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The Laffer curve for rules of origin[☆]

Keith Head[a,b,*], Thierry Mayer[c,d,b], Marc Melitz[e,b,f]

[a] Sauder School of Business, University of British Columbia, Canada
[b] CEPR, United Kingdom
[c] Sciences Po, France
[d] CEPII, France
[e] Harvard University, United States of America
[f] NBER, United States of America

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ABSTRACT

Firms in regional trade areas choose whether to comply with rules of origin (RoO) or pay a tariff penalty. Stricter content requirements initially expand regional part sourcing, but contract it when set at levels above a threshold, analogously to the Laffer curve for taxes. We calibrate the model to fit part cost shares for autos sold in North America. The effects of the 75% RoO imposed in 2020 depend on the relevant tariff and the ability to relocate assembly. With fixed assembly locations, the higher RoO reduces employment in all three countries for cars, where tariffs are low. For trucks, the 25% US tariff induces more compliance in Canada and Mexico, increasing employment in those countries. With the option to relocate assembly, higher RoOs redistribute employment to the US, but Canada and Mexico lose more, leading to a half percent decline in North American employment for both cars and trucks.

1. Introduction

The increasingly global structure of supply chains draws attention to the rules of origin (RoO) specified inside regional trade agreements (RTAs). The rules specify where an imported good was made.[1] If the rule originates the good inside the RTA then it will usually enter duty-free. Otherwise, the importing firm must pay the Most Favored Nation (MFN) tariff that the importing country applies to non-members. For autos to qualify for the preferential tariff treatment offered by the RTA, that good must meet a regional content requirement (RCR). With localized supply structures, compliance is straightforward, but the parts making up modern goods often come from origins spanning the world. As RTAs proliferated at the same time as value chains globalized, RoOs are increasingly used as a protectionist device to shelter domestic suppliers.

Historically, there have been numerous shifts, both up and down, in the RCR. For example, the 1965 US-Canada Auto Pact used a 50% content rule. This was raised to 62.5% when the North American Free Trade Agreement (NAFTA) was enacted in 1994. The Transpacific Partnership (TPP) proposed to lower the rule to just 45% in 2016, before a new US President pulled the country out of the agreement in 2017. The United States then proposed to raise the NAFTA content requirement to 85% for autos. Canada and Mexico balked at such a high rate, and the US negotiators finally settled on an increase to 75%, bolstered with additional binding

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* Corresponding author at: Sauder School of Business, University of British Columbia, Canada.
E-mail addresses: keith.head@sauder.ubc.ca (K. Head), thierry.mayer@sciencespo.fr (T. Mayer), mmelitz@harvard.edu (M. Melitz).

[1] The WTO page on RoOs, https://www.wto.org/english/tratop_e/roi_e/roi_info_e.htm provides more details.

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requirements. In this capsule history we see no sign of a consensus on the ideal restrictiveness of rules of origin. In addition, the protectionist motives for the RoOs clearly contradict their original motivation as a tool to prevent "tariff hopping" within an RTA—wherein imports circumvent higher tariff destinations within an RTA through lower tariff entry points: First, only a very low RoO would be required to prevent this kind of circumvention.[2] Second, at least in North America, the pressure for higher RoOs mainly comes from the *low* MFN country, the US, who would stand to gain from facilitating evasion of the higher MFN tariffs in Canada and Mexico.

This paper points to the potential for stricter rules to be counterproductive—even if their goal is purely protectionist. Consider a simple, but representative, example. A vehicle assembler in Mexico obtains engines within North America in order to comply with the old rules of origins but sources transmissions from Japan. Compliance with USMCA rules would require finding a North American source for the transmission. Suppose this new sourcing decision raises costs by more than the MFN tariff imposed at the destination.[3] Then it would not be worth complying with the stricter RoO. Once vehicle sales within North America are no longer compliant with the more restrictive rules, the producer no longer has an incentive to locate engine production within USMCA. They can then select their preferred location outside North America.

The scope for perverse effects expands when the firm has the option to relocate assembly as well, which it may well do, given that non-compliance with the rule of origin precludes the use of tariff preferences. Once vehicle assembly moves out of the region, the incentive to source any part from within the region declines since the imported vehicle must pay the full tariff regardless of the source of its parts. This associated decrease in regional part demand is magnified by trade costs for parts—because the relocation of assembly then increases the delivered cost for regional parts. Those incentives for the relocation of part production and assembly will hold for vehicles intended for USMCA consumers—but will be particularly salient for vehicles currently assembled in the USMCA area for export to other regions.

We develop a theoretical model that highlights these competing incentives that a tighter RoO induces on the relocation of production into and out of an RTA area. The model shows how the negative impact on relocation out of the RTA increasingly dominates as the RoOs are tightened. We show that with a continuum of parts, the mechanisms described above naturally lead to what we call a rule of origin Laffer curve. Initial increases in local content requirements shift parts production inside the region, whereas a sufficiently strict rule depresses regional parts production. With the option to relocate assembly, the final share of parts produced within the region can be lower than it would have been without any RoO. As with the Laffer curve for taxes, governments will want to avoid being on the wrong side of the Laffer curve's peak. At the extreme where the government planner only considers domestic production and employment – entirely neglecting the impact for consumers – the preferred policy will be at the peak of the Laffer for the relevant production or employment Laffer curve.

Two related papers address our question of interest, which is whether even as protectionist devices, strict rules of origin could fail to achieve their goals. The earliest work we know of in this vein is Grossman (1981). Grossman's Proposition 3 states that small increases in local content requirements have ambiguous effects on industry value added, defined as the sum of value added in components and in final goods. Industry output is more likely to fall the less sensitive intermediate production is to its price and the more sensitive is final good production to the intermediate input price. In our setup we consider potentially large increases in content requirements. A key result in our setup is that value added in just the component sector can decline. While our main result does not work via declines in final goods production, we show quantitatively how they exacerbate the negative effect on components.

Ju and Krishna (2002) continue the investigation of ambiguous effects of stricter rules launched by Grossman (1981). The key novelty of their setup is that *ex ante* identical firms potentially choose different equilibrium responses to the input requirements. There are regions in their model in which some firms comply, but others opt to just pay the MFN tariff. This can lead to non-monotonic impacts of RoOs. In contrast to their model, the firms in our framework are fundamentally heterogeneous, with some having pre-determined tendencies towards offshore sourcing of parts. This smooths out the response to policy changes, and captures the substantial empirical variations in content shares for the auto industry. Ornelas and Turner (2022) adopt a different approach emphasizing relationship-specific investment under incomplete contracts. This gives rise to a role for stricter RoOs to solve the associated under-investment problem.

RoOs generate a very specific type of friction on the import of intermediate goods. A key mechanism in our model is that limiting the use of imported intermediates will tend to raise costs. This assumption finds support in a well-established empirical literature examining the broader impact of access to imported intermediate inputs on firm performance. These studies all find that improved access to intermediate inputs lead to sizable cost and productivity gains for the affected firms.[4]

Some recent studies have focused more specifically on the impact of compliance frictions associated with RoOs. There too, the impact on firm performance is substantial. Demidova et al. (2012) find that Bangladeshi firms that are less affected by stringent rules of origins are 21% more productive than firms that are more affected by those rules. Sytsma (2022) estimates that rules of origin effectively cut the preferential margin faced by Bangladeshi apparel exporters by three-fourths. When the EU eased those rules, the number of exporters to the EU increased. Bombarda and Gamberoni (2013) similarly finds that when the EU allowed exporters to cumulate content across FTA partner countries, this stimulated both the extensive and intensive margins of exporting

[2] Felbermayr et al. (2019) show that for 86% of bilateral product pairs, tariff circumvention is unprofitable due to small differences in MFN tariffs and non-negligible transportation costs.

[3] For vehicles made in Mexico, the main market is often the US, which charges a 2.5% MFN on cars and a 25% MFN on pickup trucks and vans.

[4] See Amiti and Konings (2007), Bombardini et al. (2021), Goldberg et al. (2010), Gopinath and Neiman (2014), and Halpern et al. (2015).

to and from the EU. Anson et al. (2005) find that the compliance costs associated with NAFTA rules of origins on Mexican firms amount to the equivalent of a 6% *ad valorem* tariff on the affected intermediate goods. That cost is high enough to negate the tariff advantage for many Mexican exporters to the U.S. and Canada relative to exporters from countries outside NAFTA. Conconi et al. (2018) empirically demonstrate the "cascade effect" whereby rules of origin shift protection from final goods to intermediate inputs. In particular, they find that imports of intermediates goods from third countries decline relative to NAFTA partners.

Methodologically, our model owes its greatest debt to the continuum model of sourcing introduced by Eaton and Kortum (2002), as well as the EK-within-the-firm models of Tintelnot (2017) and Antras et al. (2017). We use the same parametrized continuum of part cost assumption, which allows us to formalize how global value chains adjust to RoOs. We can then derive the Laffer curve result for the non-monotonic impact of stricter RoOs on regional part sourcing. This stands in sharp contrast to the case of a single part, where stricter RoOs monotonically increase regional part sourcing. When this effect is reversed with multiple parts, stricter RoOs not only raise domestic costs, but also reduce the share of regional parts used in production. Lower final good production levels induced by the higher costs further reduce demand for regional parts.[5]

This paper is organized as follows. We begin with a parsimonious model that illustrates the basic trade-off associated with RoOs in Section 2. The baseline model takes assembly locations as fixed. Section 3 allows for assembly relocation. We first consider the option of relocating assembly within the region. We show how this gives trade negotiators in the largest country an incentive to push for stricter content requirements as this then induces relocation of assembly to that country (and away from smaller countries in the region). This fits the anecdotal evidence for the new USMCA, as the US negotiators pushed for substantially higher requirements than those desired by the Canadian and Mexican negotiators. Section 3 also considers the option of relocating assembly outside the region and introduces differences in the trade costs to deliver parts to the two assembly locations. We show how such trade costs along with the assembly relocation choice amplify the negative impact of higher content requirements for regional part sourcing. High content requirements can then lead to a lower regional part share than in the absence of any content rules, as firms relocate assembly outside the region.

Section 4 then uses carline-level data on NAFTA cost shares to estimate the core parameters of our model when assembly location is fixed in the short-run. To fit the data more closely, we extend the basic model of Section 2 to incorporate additional sources of heterogeneity. The calibrated model yields a Laffer curve disciplined by the data for the North American vehicle industry. Overall, this calibration reveals that the stricter RoO brought in by the USMCA appears to take the North American content share close to its maximum value. This also holds when we construct separate Laffer curves for cars and light trucks, and by North American assembly location—except for trucks assembled in Canada and Mexico. The high 25% tariff imposed by the United States for non-compliant trucks imported from those locations makes non-compliance so costly that almost all trucks assembled in those locations comply with the higher USMCA content requirements.

However, these calibrations omit the USMCA's negative impact on vehicle production within North America and the derived demand for regional parts. In order to quantify this impact and the resulting consequences for both part and assembly employment, we add more structure for competition, demand, and employment. In Appendix E, we develop an exact hat algebra method in the tradition of Dekle et al. (2007) to aggregate price and quantity changes across different sets of carlines. This allows us to construct additional Laffer curves for part employment and combined part and assembly employment that incorporate the negative impact of stricter content requirements on vehicle production. Those adjustments significantly impact the shapes of the resulting Laffer curves: We find that the stricter USMCA content requirements – relative to NAFTA – *negatively* affect combined employment, except for the case of trucks assembled in Canada and Mexico that we previously mentioned (though the price increases and resulting consumer surplus losses are more severe for those trucks.) In other words, setting aside those two cases, the new USMCA content requirements are on the "wrong" side of the combined employment Laffer curve: they lead to decreases in *both* overall employment (production levels) and consumer surplus.

Lastly, we construct the part share and employment Laffer curves that allow for assembly relocation. This captures the longer-run predictions for the impact of stricter content requirements. We use the same calibration as the case of fixed assembly location, but allow vehicle producers to relocate assembly either within North America (to one of the other two countries) or to a Foreign location. To do this, we compute the tariff and transport cost differentials associated with those relocations. Two main messages arise from this exercise: (1) In the long-run when assembly location is endogenous, the potential for content requirements to raise regional part sourcing is significantly muted: as the RoO becomes stricter, producers relocate assembly rather than comply with the stricter rules. For both cars and trucks and the three North American assembly locations, the stricter content requirements in the new USMCA are ineffective in raising regional part production and the associated part employment: The small increases in part sourcing are wiped out by reductions in vehicle production due to higher prices. (2) The overall employment responses are dominated by the assembly relocation from Mexico and Canada to the United States. In the long run, this leads to substantial employment gains for the United States, paired with severe losses for both Canada and Mexico. Stricter RoOs redistribute jobs within the region, but the RoO-induced rise in costs has two negative net effects: It pushes some auto manufacturers to relocate abroad and shrinks the market share of the carlines that opt to remain in the region. For North America as a whole, our model predicts −0.6% employment reductions (parts and assembly) for cars and −0.4% for trucks.

[5] This channel is also operative when there is a single part.

2. Sourcing and RoOs with a continuum of parts

Rules of origins generate competing incentives for the location of both parts and assembly within a regional trade area (RTA). Stricter rules intended to relocate the production of parts inside the RTA could potentially induce an opposite relocation effect away from the RTA. We develop a simple model focusing on the sourcing decision for parts in order to demonstrate how these opposing effects arise naturally in this setting and how the negative effects are likely to dominate when RoOs are tightened beyond a threshold. In order to focus on those opposing forces for part sourcing, we initially abstract from the associated assembly location decision. We then show how this additional choice interacts with the part sourcing decision and compliance with the RoO.

2.1. Model setup

A firm uses a unit continuum of parts that can be sourced either domestically (within the RTA) or from a Foreign source. For now, we ignore any heterogeneity between countries in the RTA and only consider a single sourcing location for parts. Later on, we will introduce this heterogeneity when we endogenize the assembly location choice (as well as the part sourcing) between different countries in the RTA. Thus, we refer to the regional part share as "domestic"—in contrast to the Foreign-sourced parts. The cost of each part is drawn from a Weibull distribution with parameter $\theta \geq 1$. We normalize the mean cost of domestic parts (over the unit continuum) to one. The mean cost of the foreign sourced parts is $\delta > 0$.[6] This parameter varies across firms. Firms with $\delta > 1$ have a lower domestic production cost for parts. For now, we ignore assembly costs and the assembly location choice, and focus on the compliance choice to a RoO.

2.1.1. Free trade (no policy restrictions)

If a firm δ faces no restriction on part sourcing, it will source an unrestricted share of domestic parts

$$\chi_U(\delta) = \left(1 + \delta^{-\theta}\right)^{-1}. \tag{1}$$

Given the Weibull cost draws, this sourcing decision equalizes the average cost of domestic-sourced parts with the average cost of foreign-sourced parts. This average cost is equal to $C_U(\delta) = \chi_U(\delta)^{1/\theta}$ and also captures the total cost of parts (given the unit continuum). Both $\chi_U(\delta)$ and $C_U(\delta)$ are increasing in δ: A firm with a bigger foreign cost advantage (lower δ) will choose a lower domestic part share and benefit from a lower total cost.

2.1.2. Rules of origin

A RoO mandates that firms source a minimum share χ_R of their parts domestically (or alternatively a minimum domestic cost share), or face an MFN tariff rate on the final good exported within the RTA. We model this additional cost as an average tariff $\tau > 1$ incurred across all final good units produced. In the appendix, we show how this average tariff is scaled down from the MFN tariff rate as the share of within-RTA exports decreases when final good demand has a constant price elasticity (there is no scaling down of the MFN rate when all units are exported within the RTA, and final good demand is irrelevant). Since final good demand is only relevant for the determination of the average tariff τ, we do not introduce it explicitly.[7] If a firm chooses to comply with the RoO and avoid the tariff, it sources progressively more expensive parts domestically (relative to foreign-sourced) until the minimum threshold is met. Those sourcing choices are identical to the ones a firm would make if a tariff $\rho > 1$ were imposed on foreign parts (with the tariff revenue subsequently rebated back to the firm). A tariff rate of ρ would induce a firm to increase its domestic share above $\chi_U(\delta)$ to

$$\chi_R = \left[1 + (\rho\delta)^{-\theta}\right]^{-1}. \tag{2}$$

If this firm were paying the tariff cost, its hypothetical total part cost would rise from $C_U(\delta)$ to $\chi_R^{1/\theta}$, which represents both the average cost of domestically sourced parts, as well as the average cost of foreign sourced parts *inclusive* of the hypothetical tariff.[8]

If a binding RoO $\chi_R > \chi_U(\delta)$ were mandated instead of a tariff, then the firm would make the same sourcing decisions, but its cost would not include the tariff ρ yielding a total part cost:

$$\begin{aligned} C(\chi_R, \delta) &= \chi_R \cdot \chi_R^{1/\theta} + \left(1 - \chi_R\right) \cdot \frac{\chi_R^{1/\theta}}{\rho} \\ &= \chi_R^{\frac{1+\theta}{\theta}} + \left(1 - \chi_R\right)^{\frac{1+\theta}{\theta}} \delta, \end{aligned} \tag{3}$$

[6] In other words the distributions of the cost draws c sourced domestically ($i = D$) and in Foreign ($i = F$) are distributed $G_i(c) = 1 - \exp\left(-\left(c/\gamma_i\right)^{\theta}\right)$ with $\gamma_D \equiv \gamma, \gamma_F \equiv \delta\gamma, \gamma \equiv 1/\Gamma(1 + 1/\theta)$.

[7] With constant price elasticity demand, we show how this scaling down for the average tariff depends only on exogenous demand parameters (market demands across regions) and trade costs (transport costs and MFN tariffs). Thus, the decomposition of this average τ between the export share and the MFN tariff is inconsequential for a given final good. However, this means that variation in τ across products is possible even when goods face the same MFN tariff when there is variation in demand across products. We discuss the implications of variation in τ later on.

[8] Recall that the Weibull draws induce sourcing decisions that equalize the average cost parts by sourcing location.

using $\rho = \left[\chi_R / \left(1-\chi_R\right)\right]^{1/\theta} \delta^{-1}$ from (2). The first term captures the cost of domestic parts (same cost as under the tariff ρ) while the second one captures the cost of foreign parts rebated by the tariff ρ. The cost share associated with this RoO χ_R is:

$$\lambda(\chi_R, \delta) = \frac{\chi_R^{\frac{1+\theta}{\theta}}}{C(\chi_R, \delta)} = \left[1 + \left(\frac{1-\chi_R}{\chi_R}\right)^{\frac{1+\theta}{\theta}} \delta\right]^{-1}. \tag{4}$$

Note that $\lambda(\chi_R, \delta)$ is monotonic in χ_R so we can think of a RoO as being imposed based on the share of parts χ_R or alternatively its cost share λ_R. Most free trade agreements specify the regional content rule of origin as cost shares though in some cases specific parts are mandated to be sourced with the region. This makes the rule look more like a part share rule. In the case where a cost-share λ_R is mandated, the required part share χ_R is just given by the inverse:

$$\chi_R = \left[1 + \left(\frac{\lambda_R^{-1} - 1}{\delta}\right)^{\frac{\theta}{\theta+1}}\right]^{-1}. \tag{5}$$

For the ensuing analysis, we assume that the rule is specified in terms of a part share χ_R, though this can be the outcome of the inversion above based on a cost-share rule λ_R.

A binding RoO $\chi_R > \chi_U(\delta)$ engenders an increase in the firm's total part cost relative to its unrestricted (lower bound) cost $C_U(\delta)$ given by

$$\tilde{C}(\chi_R, \delta) = \begin{cases} C(\chi_R, \delta)/C_U(\delta) > 1 & \chi_R > \chi_U(\delta), \\ 1 & \chi_R \leq \chi_U(\delta). \end{cases} \tag{6}$$

$\tilde{C}(\chi_R, \delta)$ is strictly decreasing in δ when the RoO is binding: firms with a greater comparative advantage in Foreign parts (lower δ) face a higher cost penalty of compliance for a given RoO χ_R. Absent the RoO, those firms would have chosen a lower part share $\chi_U(\delta) < \chi_R$, and it is therefore more costly to increase that share to χ_R. And $\tilde{C}(\chi_R, \delta)$ is strictly increasing in χ_R when the RoO is binding: a higher RoO induces higher cost penalties for all firms. However, a RoO need not be binding, as some firms with high δ may have an unrestricted part share *above* the RoO: $\chi_U(\delta) \geq \chi_R$. This will be the case for firms with $\delta \geq \delta^\circ$ such that $\chi_U(\delta^\circ) = \chi_R$, implying $\delta^\circ = \left(\chi_R^{-1} - 1\right)^{-1/\theta}$. Those firms can stick with their unrestricted part share $\chi_U(\delta)$ and still comply with the RoO with no cost penalty: $\tilde{C}(\chi_R, \delta) = 1,\ \forall \delta \geq \delta^\circ$.

2.1.3. Comparison with Eaton–Kortum model of trade in goods

A rule of origin χ_R has the same welfare impact – the cost increase $\tilde{C}(\chi_R, \delta)$ imposed on firms – as an equivalent tariff ρ (which raises the domestic part share to χ_R) would in a two-country version of the Eaton and Kortum (2002) model, where $\delta^{-\theta}$ represents the foreign country's technological (absolute) advantage. But those welfare gains are no longer iso-elastic in the domestic share χ_R (with elasticity $1/\theta$) due to the revenue generated by the tariff. Just like a tariff, a rule of origin χ_R generates a distortion with no direct cost—unlike an iceberg trade cost. At the unrestricted equilibrium the elasticity of welfare with respect to either the rule χ_R or the tariff ρ is zero. However, that welfare elasticity then increases monotonically with either χ_R or ρ. The welfare penalty from a rule of origin – just like a tariff – is therefore more convex than a real cost that induces the same sourcing decisions. In the limit when $\chi_R = 1$, all compliant firms are forced into autarky sourcing with a part cost $C(1, \delta) = 1$ (the average cost of domestically sourced parts). Their cost disadvantage $\tilde{C}(1, \delta) = C_U(\delta)^{-1} = \chi_U(\delta)^{-1/\theta}$ is equal to the full gains from trade (autarky to free trade) in the E-K model representation.[9]

2.2. Compliance

The top panel of Fig. 1 shows the cost penalty $\tilde{C}(\chi_R, \delta)$ for three firms with different δs as a function of the RoO χ_R. In this and all subsequent figures, we set $\theta = 4$ and a tariff level $\tau = 1.1$. As previously mentioned, this cost penalty increases with χ_R and is higher for firms with higher foreign-cost advantages (lower δ). We also see when a RoO χ_R is low enough ($\chi_R \leq \chi_U(\delta) \iff \delta \geq \delta^\circ$) to be non-binding, eliminating the cost penalty: $\tilde{C}(\chi_R, \delta) = 1$. As also anticipated, a given rule of origin χ_R is more likely to be binding for the firms with higher foreign-cost advantages as their unrestricted part share $\chi_U(\delta)$ is lower.

The policy maker cannot force firms to comply with a RoO χ_R. A firm δ can choose to be non-compliant with the rule and pay the average tariff τ. It will do so whenever $\tilde{C}(\chi_R, \delta) \geq \tau$, and then revert to its unconstrained part sourcing with domestic share $\chi_U(\delta)$ and cost $C_U(\delta) = \chi_U(\delta)^{1/\theta}$. This leads to a cutoff rule for compliance: Only firms with $\delta > \delta^*$ such that $\tilde{C}(\chi_R, \delta^*) = \tau$ will comply with the RoO χ_R given a tariff punishment τ. δ^* increases monotonically with the rule of origin χ_R: A tougher RoO leads more firms to choose non-compliance. However, even in the autarky sourcing limit when $\chi_R = 1$, δ^* is finite: $\lim_{\chi_R \to 1} \delta^* = \left(\tau^\theta - 1\right)^{-1/\theta} \equiv \bar{\delta}$. Firms with δ above this threshold will comply with any RoO as their autarky cost disadvantage $\tilde{C}(1, \delta)$ is bounded and below the tariff cost τ. This is the case for the firm with $\delta = 1.25$ in the figure.

[9] $\lim_{\chi_R \to 1} \delta^\circ = +\infty$, so a RoO $\chi_R = 1$ is binding for all firms.

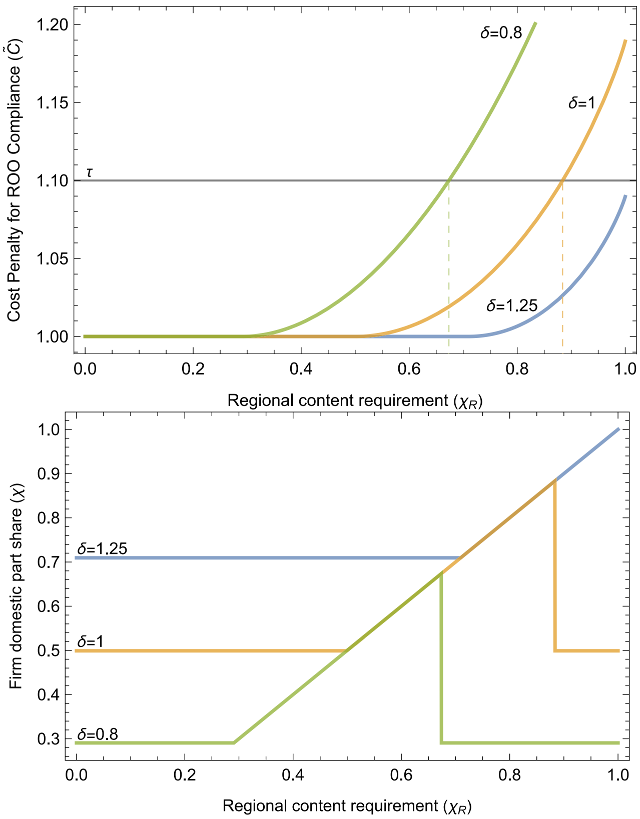

Fig. 1. Compliance Cost and Sourcing Decision for 3 Firms.

And conversely more firms with $\delta > \delta^*$ comply as the RoO becomes progressively looser and δ^* decreases. Some of those firms with $\delta \geq \delta^\circ > \delta^*$ do not face any compliance penalty, $\tilde{C}(\chi_R, \delta) = 1$, because their unrestricted part share $\chi_U(\delta)$ is above the RoO χ_R. Those firms comply with the RoO, but choose their unrestricted part share $\chi_U(\delta)$, whereas the remaining compliant firms face a cost penalty $\tilde{C}(\chi_R, \delta) > 1$ and set their part share at the level of the RoO χ_R. We label the latter firms compliant-constrained; and the former compliant-unconstrained. To summarize, only the compliant-constrained firms choose a part share at the level of the RoO χ_R. The remaining firms are either compliant-unconstrained or non-compliant, and they choose their unrestricted part share $\chi_U(\delta)$. Letting $\chi(\chi_R, \tau, \delta)$ denote the chosen part share, then:

$$\chi(\chi_R, \tau, \delta) = \begin{cases} \chi_R & \delta^* < \delta \leq \delta^\circ, \\ \chi_U(\delta) & \text{otherwise.} \end{cases} \tag{7}$$

The bottom panel of Fig. 1 shows this chosen part share as a function of the RoO χ_R for the same three firms. When the RoO is low enough, all three firms are compliant-unconstrained and choose their respective part share $\chi_U(\delta)$. As the RoO increases, it starts binding for those firms and induces a cost penalty above 1. The firms then become compliant-constrained and set a part share at the level of the RoO χ_R. As the RoO increases even further, the cost penalty rises above the average tariff τ for the two firms with the lower δs, and they then stop complying (non-compliant) and revert to their unconstrained part share $\chi_U(\delta)$.

Fig. 2 plots the cost penalty $\tilde{C}(\chi_R, \delta)$ (top panel) and chosen part share $\chi(\chi_R, \tau, \delta)$ (bottom panel, in yellow) against the firm's δ for a given χ_R (equal to 0.7 in the figure). The bottom panel also adds the unrestricted part share $\chi_U(\delta)$ (in blue). This highlights the determination of the δ° cutoff at $\chi_U(\delta^\circ) = \chi_R$. The determination of the δ^* cutoff at $\tilde{C}(\chi_R, \delta^*) = \tau$ is shown in the top panel. As we previously mentioned, the cost penalty $\tilde{C}(\chi_R, \delta)$ is strictly decreasing in δ whenever the RoO χ_R is binding for the compliant-constrained firms with $\delta < \delta^\circ$, and then flat at one for the compliant-unconstrained firms with $\delta \geq \delta^\circ$. The bottom panel highlights how the compliant-constrained firms increase their domestic part share to satisfy the RoO χ_R and thus deviate from their unconstrained part share $\chi_U(\delta)$; whereas the compliant-unconstrained need not deviate from that unconstrained share in order to comply with the RoO.

2.3. Laffer curve for rules of origin

The aggregate domestic part share is given by $X(\chi_R) = \int \chi(\chi_R, \tau, \delta) dF(\tau, \delta)$, where $F(\tau, \delta)$ is the joint distribution of firm-level δs and τs . For now, we assume a common average τ across firms and focus on the cross-firm variation in δ, which implies a univariate

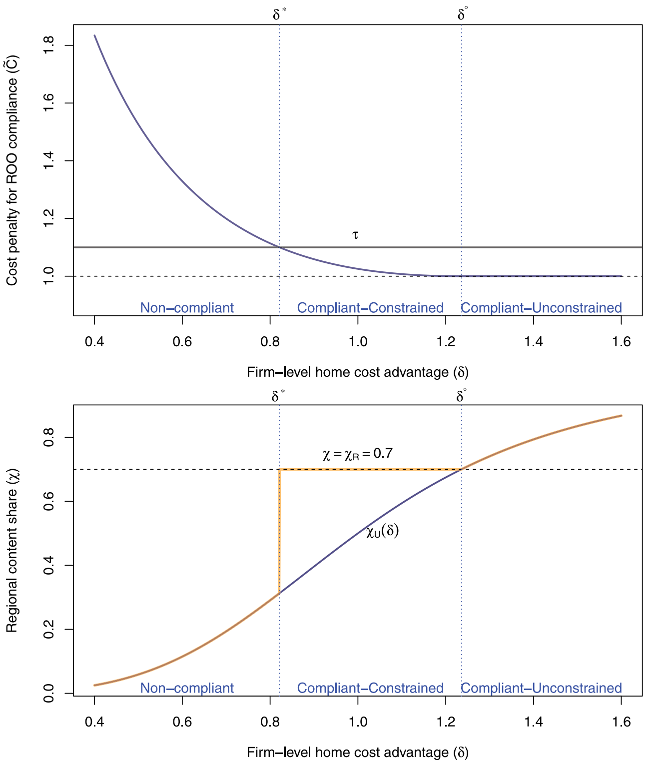

Fig. 2. Compliance Cost and Compliance Decision.

distribution $F(\delta)$ for the aggregate part share $X(\chi_R)$. The variation in that domestic part share at the firm-level as a function of χ_R was shown in the bottom panel of Fig. 1 for three firms with different δs. For firms with high $\delta \geq \bar{\delta}$ that always comply with any RoO (including $\chi_R = 1$), such as the firm with $\delta = 1.25$ in the Figure, a higher χ_R can never induce a lower part share choice $\chi(\chi_R, \tau, \delta)$: Either the firm is compliant-unconstrained and thus does not adjust its part share with the RoO χ_R, or it is compliant-constrained and increases its part share one-for-one with the RoO χ_R. However, the firms with $\delta < \bar{\delta}$ will respond to a higher RoO χ_R by adjusting their domestic part share non-monotonically: As χ_R increases from 0, it will initially induce a firm to increase its part share (when the rise in χ_R induces the firm to switch from compliant-unconstrained to compliant-constrained); but further increases in χ_R will then induce a sharp drop in the part share once the firm switches to non-compliance. This hump-shaped response is shown for the remaining two firms with $\delta = \{0.8, 1\}$ in the Figure (more accurately, a "triangle" shape for a single firm).

Aggregating over a distribution $F(\delta)$ for $\delta < \bar{\delta}$ smoothes out the firm-level responses into a smooth hump-shaped aggregate part share $X(\chi_R)$ curve. This curve starts (at $X(0)$) and stops (at $X(1)$) at the same level when all firms (again, with $\delta < \bar{\delta}$) choose their unconstrained part share $\chi_U(\delta)$[10]:

$$X(0) = X(1) = \frac{1}{F(\bar{\delta})} \int_0^{\bar{\delta}} \chi_U(\delta) dF(\delta).$$

We call this hump-shaped part share curve a Laffer curve for Rules of Origin due to its similarity with the hump-shaped Laffer curve for income tax as a function of the tax rate. Just like that original Laffer curve, a higher RoO χ_R is intended to increase the aggregate part share $X(\chi_R)$ by forcing firms to comply with a higher threshold—but can lead to decreases in $X(\chi_R)$ by inducing firms to switch to non-compliance.

The aggregate part share $X(\chi_R)$ for the set of always compliers (with $\delta \geq \bar{\delta}$) is non-decreasing (and must be increasing once χ_R rises above a threshold). If the distribution $F(\delta)$ is such that the set of always-compliers is dominant, then it is possible for the aggregate curve $X(\chi_R)$ to inherit that non-decreasing shape. Otherwise, the $X(\chi_R)$ curve will still be hump-shaped, but with $X(1) > X(0)$ due to the always-compliers.

We now parametrize $F(\delta)$ to quantitatively assess the Laffer curve for $X(\chi_R)$. We use a symmetric distribution for the percent cost advantage for domestic production $\log \delta$ (whenever negative, this represents the percent cost advantage in favor of Foreign part production). We use a Normal distribution for this cost advantage $\log \delta$ centered at zero so that there is no country-wide comparative

[10] Recall that when $\chi_R = 0$, all firms are compliant-unconstrained; and when $\chi_R = 1$, all firms with $\delta < \bar{\delta}$ are non-compliant. In both cases, all firms choose the same part share $\chi_U(\delta)$.

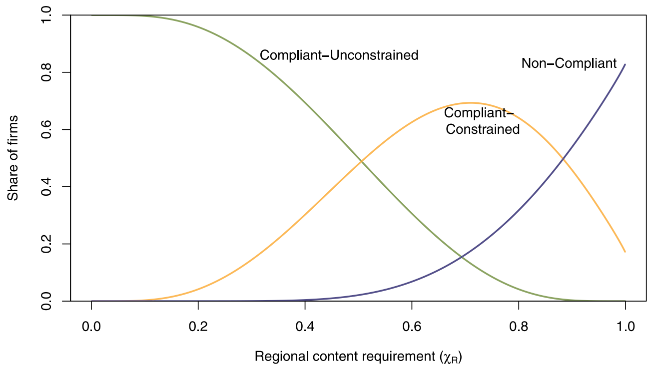

Fig. 3. Compliance with Rule of Origin: Firm shares.

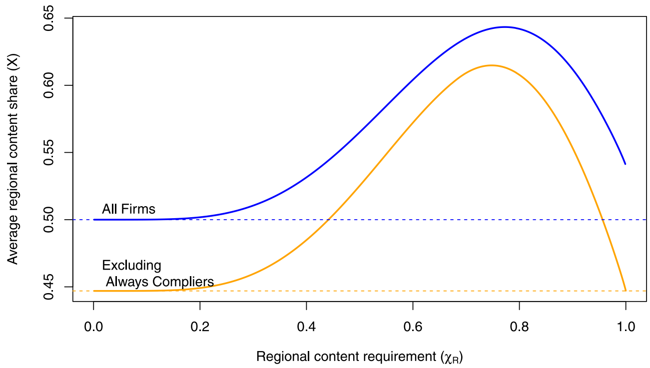

Fig. 4. Laffer curve for domestic part production.

advantage in favor of either country. And we set the standard deviation at 0.2. This implies that 10 percent of firms have a cost advantage multiplier greater than 1.39 (5 percent in favor of either domestic or Foreign); 20 percent have a cost advantage multiplier greater than 1.29 (10 percent in favor of either country); and lastly that 50 percent of firms have a cost advantage multiplier greater than 1.14 (25 percent in favor of either country). We continue with the same other parameter choices that we used in the earlier Figures: $\theta = 4$ and $\tau = 1.1$.

Fig. 3 shows how the shares of non-compliant (blue), compliant-constrained (yellow), and compliant-unconstrained (green) firms vary as a function of the RoO χ_R (those three shares always add up to 1). As we previously described in the general case, the share of compliant-constrained firms (orange curve) initially increases from zero as the RoO is tightened (increasing χ_R). Those firms increase their domestic part share and generate an increase in the aggregate domestic part share $X(\chi_R)$. However, as the RoO is further tightened, some complying firms (blue curve, with the highest cost differentials in favor of Foreign, i.e. the lowest δs) stop complying and revert to their lower unconstrained part share $\chi_U(\delta)$ (and pay the tariff τ). As we described for the general case, this share must monotonically increase with the rule of origin (which raises the compliance cutoff δ^*) regardless of the parametrization for δ. The remaining set of compliant-unconstrained firms (green curve) decreases monotonically from 1 to 0. This holds regardless of the parametrization choice for δ as the δ° cutoff increases with χ_R.

Given our parametrization, there are roughly 17% of firms with $\delta \geq \bar{\delta}$ that are always-compliers, as represented by the limit for the yellow curve as $\chi_R \to 1$. Among those firms, a tightening of the rule of origin χ_R must lead to an increase in the average domestic share. We previously argued that, excluding those firms, the aggregate domestic cost share must exhibit a Laffer curve, regardless of the parametrization choice for δ. We show the Laffer curves induced by our specific parametrization in Fig. 4. The yellow curve excludes those 17% of firms. We see that the aggregate share initially increases and then returns to its initial level as $\chi_R \to 1$. The blue curve shows the aggregate share for all firms. Because that excluded portion of firms is not too substantial, we see that the $X(\chi_R)$ curve remains hump shaped, though with $X(1) > X(0)$ as we previously described for the general case.

In the appendix, we show how different parametrization choices affect the shape of the Laffer curve for $X(\chi_R)$. Those curves are displayed in Appendix Figure C.1 for high and low parameter settings for μ, σ, θ, and τ. While the $X(\chi_R)$ curve changes shape and position in intuitive ways, the basic hump-shaped Laffer curve is robust to those deviations from our benchmark parameter settings.

Our model based on multiple-part sourcing is key in generating this Laffer curve. In contrast, a similar model with a single part would generate a non-decreasing part share curve $X(\chi_R)$. This is illustrated in Fig. 5, which replicates Fig. 1 when there is a single-part decision made by the three firms. For the purpose of illustration, we assume that half of the firm's part purchases are exogenously sourced within the RTA (domestic) and the firm is considering the sourcing decision for a single part accounting for the

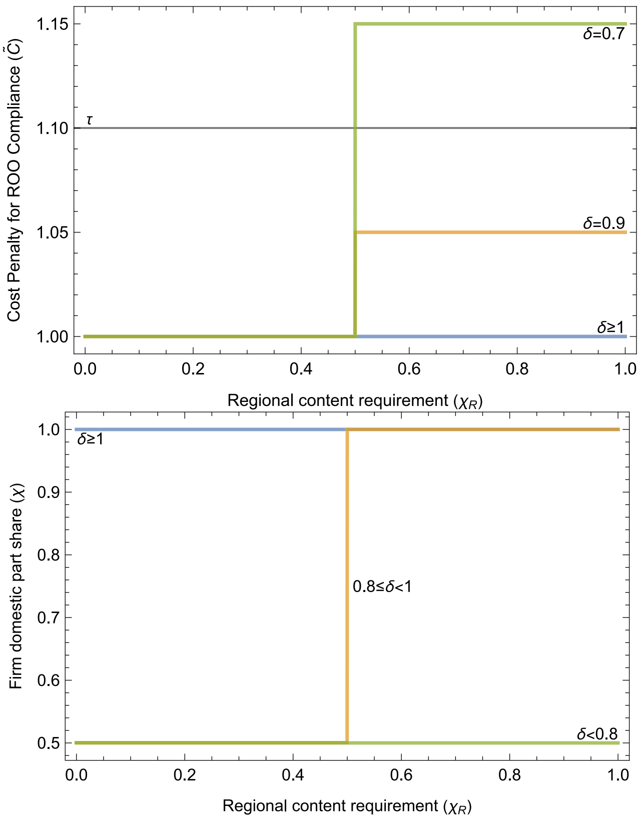

Fig. 5. Compliance cost and sourcing decision with a single part.

other half of its part purchases. The choice of this part threshold is irrelevant for our argument, and could further be heterogeneous across firms.

When the RoO χ_R is below 50%, all firms are compliant-unconstrained, regardless of their δ. Once χ_R rises above 50%, then Foreign-sourcing this single part induces non-compliance with the RoO. Firms with $\delta < 0.8$ choose this option and pay the 10% average tariff penalty because that leads to a lower cost than domestic-sourcing of the part . On the other hand, firms with $0.8 \leq \delta < 1$ choose compliance (constrained) and switch from Foreign to domestic sourcing. And firms with $\delta \geq 1$ are always compliant-unconstrained: they prefer domestic-sourcing for that part regardless of the RoO. Thus, Fig. 5 illustrates how, across the distribution of δs, a higher RoO χ_R can only induce firms to increase their domestic part share (or maintain it at its current level): There is no non-monotonic response at the firm-level, and there hence cannot be a non-monotonic response when aggregating over firms.

3. Extension to assembly location choice

In order to highlight the inherent forces generating a Laffer-curve effect for a RoO policy, we have focused on the part sourcing decision and abstracted from the associated decision regarding the location of assembly. We now extend our model to incorporate the choice of assembly: first in another country within the RTA, then in a Foreign country outside the RTA. The compliance decision is then linked with the location of assembly, yet a similar Laffer-curve effect for the rule of origin prevails. When we add trade costs in parts between the RTA and the Foreign location, we show how the negative impact of tighter RoOs for the aggregate regional part share is amplified. When those trade costs are high enough, a tighter RoO can then lower the part share below its initial level with no RoO. And for even higher trade costs, the hump in the Laffer curve can disappear and then tighter RoOs can only lead to decreases in the regional part share as firms relocate assembly to Foreign. For simplicity, we restrict the analysis to the choice of a single assembly location, precluding the splitting of assembly across locations. In essence, this imposes a restriction on the returns to scale in assembly.

3.1. Intra-RTA assembly relocation

We initially consider the assembly location choice between heterogeneous countries within the RTA, and further extend the model to analyze a Foreign assembly location. A RoO policy induces heterogeneous effects across countries within an RTA because the penalty for non-compliance is only applied to within-RTA exports. Thus, a country with a larger domestic market (such as the United States within NAFTA) faces a lower average tariff penalty for non-compliance: a greater share of output is sold domestically. If this were the only dimension of heterogeneity across countries in an RTA, then all RoO-compliant-constrained assembly would relocate to the larger market with the lower average tariff penalty. We therefore introduce another dimension of cost heterogeneity tied to the location of assembly and analyze the tradeoff between the lower average tariff penalty in the larger market and an assembly cost advantage in the smaller market.

Along with a domestic assembly location (D), a firm can also choose an assembly location elsewhere in the RTA (R). We model relative differences in assembly costs between D and R as a multiplicative cost shifter ω^R. Just like we did for parts, we normalize the domestic assembly cost parameter at 1 (this involves a new normalization of costs, which now include assembly). Then, given a total part cost C, the total production cost – including assembly – is C in D and $\omega^R C$ in R. We maintain our normalization of an average part cost within the RTA to 1 relative to the average of δ for Foreign parts. This is just a choice of numeraire and subsumes adding separate Weibull cost draws for part production in both D and R.[11] As we previously mentioned, differences in domestic market sizes and MFN tariffs across D and R imply differences in the cost penalty for non-compliance with the RoO based on the assembly location choice: $\tau^R > 1$ versus $\tau^D > 1$.

Lastly, we assume that trade costs for parts within the RTA are negligible (this is reasonable for the case of NAFTA where many inter-country trade links are shorter than some intra-country trade links). In this case, any given part sourcing choice (including the unconstrained minimized cost choice) will have the same direct part cost C independent of the assembly location. That assembly location will matter because it affects the non-compliance cost penalties (τ^D, τ^R) associated with a sourcing choice, but not its direct cost C. We introduce trade costs for parts when we consider Foreign assembly locations outside of the RTA. In this case, a given sourcing choice will have different costs based on the location of assembly. The assembly location will then directly impact the firms' sourcing choice.

In all these cases, the negligible differences in trade costs for parts *within* the RTA implies that the location of part production within the RTA is irrelevant: the firm sourcing choice χ is a regional part share. The location of assembly, denoted by superscripts D and R (and later on F), will affect this sourcing choice, but it is a common one that applies to all part production locations in the RTA.

3.1.1. Part shares and cost

Regardless of the assembly location (D vs R), firms use the same unconstrained share of regional parts $\chi_U^D(\delta) = \chi_U^R(\delta) = \chi_U(\delta)$; and whenever $\delta \geq \delta^\circ$ (recall that $\chi_U(\delta^\circ) = \chi_R$), a firm can costlessly comply with the RoO at χ_R. It is then compliant-unconstrained. For assembly in D, the compliant-constrained, compliant-unconstrained, and non-compliant costs are the same as previously derived: respectively, $C^D(\chi_R, \delta) = C(\chi_R, \delta)$, $C_U^D(\delta) = C_U(\delta)$, and $\tau^D C_U^D(\delta) = \tau^D C_U(\delta)$. For assembly in R, the costs include the multiplicative assembly shifter ω^R, and the cost penalty for non-compliance is τ^R instead of τ^D. Thus, the compliant-constrained, compliant-unconstrained, and non-compliant costs are $C^R(\chi_R, \delta) = \omega^R C(\chi_R, \delta)$, $C_U^R(\delta) = \omega^R C_U(\delta)$, and $\tau^R C_U^R(\delta) = \tau^R \omega^R C_U(\delta)$. For compliant-constrained firms with $\delta < \delta^\circ$, the cost penalty associated with RoO compliance is the same for both assembly locations (and equal to our previously derived cost penalty): $\tilde{C}^D(\chi_R, \delta) = \tilde{C}^R(\chi_R, \delta) = \tilde{C}(\chi_R, \delta) = C(\chi_R, \delta)/C_U(\delta)$.

3.1.2. Compliance and assembly location

Without loss of generality (this is the only distinction between D and R), we assume that assembly production is more costly in R: $\omega^R > 1$. Thus, any firm that complies with the RoO will choose assembly in D since both the unconstrained and constrained costs $C_U^D(\delta)$ and $C^D(\chi_R, \delta)$ are shifted down by a factor of ω^R relative to the costs $C_U^R(\delta)$ and $C^R(\chi_R, \delta)$. This applies to the compliant-unconstrained firms with $\delta \geq \delta^\circ$. For firms with lower δ, they will choose between complying in D (CD) with cost $C^D(\chi_R, \delta) = C(\chi_R, \delta)$, non-compliance in D (NCD) with cost $\tau^D C_U^D(\delta) = \tau^D C_U(\delta)$, and non-compliance in R with cost $\tau^R C_U^R(\delta) = \tau^R \omega^R C_U(\delta)$. The firm will choose the option with the lowest cost:

$$\min\left\{C(\chi_R, \delta), \tau^D C_U(\delta), \tau^R \omega^R C_U(\delta)\right\} = C_U(\delta) \min\left\{\tilde{C}(\chi_R, \delta), \tau^D, \tau^R \omega^R\right\}.$$

This leads to very similar threshold conditions for the cost penalty $\tilde{C}(\chi_R, \delta)$; except that there are now two thresholds for non-compliance, τ^D and $\tau^R \omega^R$, depending on the location of assembly. These two thresholds do not depend on the firm's δ. If $\tau^D < \tau^R \omega^R$, then non-compliance in D (NCD) dominates non-compliance in R (NCR) for all firms. This case is identical to the one we previously analyzed with exogenous assembly located in D: There is a cutoff δ^* such that $\tilde{C}(\chi_R, \delta^*) = \tau^D$. Firms with δ below that cutoff choose NCD, and firm with δ above the cutoff choose CD (and those with the highest $\delta \geq \delta^\circ$ are unconstrained). When the inequality is reversed and $\tau^D > \tau^R \omega^R$ – in other words, the lower non-compliance cost penalty in favor of R outweighs its assembly cost disadvantage – then non-compliance in R (NCR) dominates non-compliance in D (NCD) for all firms. In this case, there is a higher cutoff δ^{DR*} such that[12]

$$\tilde{C}(\chi_R, \delta^{DR*}) = \tau^R \omega^R.$$

[11] If part production in D and R were subject to separate Weibull cost draws with mean δ^D and δ^R, then a firm would pick the lowest cost part leading to a Weibull distribution of cost (across both D and R) with mean $\left[\left(\delta^D\right)^{-\theta} + \left(\delta^R\right)^{-\theta}\right]^{-1/\theta}$, which we use as our new numeraire.

[12] Recall that $\tilde{C}(\chi_R, \delta)$ is decreasing in δ.

Firms with δ above that cutoff still choose compliance in D (CD), but firms with δ below that cutoff will choose non-compliance in R (NCR).

Comparative statics for the cutoff δ^{DR*} are identical to the ones we derived earlier for δ^*—since they are both based on the same cost penalty function $\tilde{C}(\chi_R, \delta)$. In particular, increases in the RoO χ_R will lead to a higher cutoff δ^{DR*}, and a relocation of assembly from D to R along with a switch from compliance to non-compliance with the RoO. Recall that this case when assembly in R is not dominated is characterized by $\tau^D > \tau^R\omega^R > \tau^R$. In words, the relatively higher assembly cost in R is more than offset by a lower tariff penalty on non-compliant intra-RTA exports. As we show later on for the case of NAFTA, the tariff penalty τs are substantially lower for the United States, due to its large domestic market and associated lower levels of intra-NAFTA exports (see Fig. 9). Thus, our model therefore explains why a country with the largest domestic market within an RTA (such as the United States for NAFTA) may prefer a higher RoO χ_R: It confers an assembly location advantage.[13]

3.2. Foreign assembly location

We now extend our assembly location choice to a foreign location, F, outside the RTA. For simplicity, we go back to a single assembly location (D) within the RTA. Extending our previous analysis to allow for another assembly location (R) within the RTA is trivial and only requires the handling of more cases.

There are two key differences associated with a Foreign assembly location (F) relative to the case of the within-RTA location (R) that we previously modeled: (1) Compliance in F is impossible because assembly within the region is a necessary condition for almost all rules of origin. This means that foreign assembly entails non-compliance (NCF) and paying the MFN tariff for exports to the RTA. (2) We can no longer assume negligible trade costs for parts between the two potential assembly locations in D and F. We model those as a symmetric iceberg cost $\kappa \geq 1$. When the assembly location was restricted to be in D, such trade costs could just be subsumed in the cost difference δ. However, this isomorphism no longer works once multiple assembly locations are available. Given an average cost differential δ for a given firm, any part will be cheaper whenever used in assembly in the same location; and conversely will be more expensive (shifted up by κ) when used in assembly in the other location.

Just like the case of the intra-NAFTA assembly location in R, we model relative differences in assembly costs between D and F as a multiplicative cost shifter ω^F. This can be either greater than 1 if assembly in F is more expensive, or less than 1 if assembly in F is cheaper. And we use the same notation τ^D and τ^F to denote the non-compliance cost penalties for NCD and NCF relative to the case of compliance CD.

Those two cases are straightforward to combine, but we do not gain intuition by doing so here. Instead, we combine options to relocate within and outside the region in the quantitative analysis in Section 5.2. So long as we maintain our assumption of negligible trade costs *within* the RTA, the sourcing choices we derive will pertain to regional part shares, irrespective of the production location for those parts within the RTA.

3.2.1. Part shares and cost

As we previously highlighted, the trade cost κ for parts now means that the location of assembly directly affects a firm's sourcing choice. We start with the *case of domestic assembly*. In this case, the trade cost κ just acts like a multiplicative cost shifter that interacts with the average cost differential δ, resulting in a relative cost $\delta\kappa$. (This is why we did not need to explicitly model the trade cost when we restricted the assembly location to D.) The part shares and cost functions are given by:

$$\chi_U^D(\delta) = \chi_U(\delta\kappa), \quad C_U^D(\delta) = C_U(\delta\kappa), \quad \text{and} \quad C^D(\chi_R, \delta) = C(\chi_R, \delta\kappa).$$

Firms will be unconstrained by the content rule when $\chi_U^D(\delta) \geq \chi_R$. This will be the case when $\delta \geq \delta^{D\circ}$, where $\chi_U^D(\delta^{D\circ}) = \chi_R$. This cutoff is shifted down from the previous cutoff by κ: $\delta^{D\circ} = \delta^\circ\kappa^{-1}$.

In the *case of foreign assembly*, the trade cost κ now increases the delivered cost of domestic parts (with an average production cost of 1) while leaving the delivered cost of Foreign parts unaffected (with an average production cost of δ). The unconstrained domestic part share is thus

$$\chi_U^F(\delta) = \frac{\kappa^{-\theta}}{\kappa^{-\theta} + \delta^{-\theta}} = \chi_U(\delta/\kappa), \tag{8}$$

and is associated with the cost

$$C_U^F(\delta) = \left(\kappa^{-\theta} + \delta^{-\theta}\right)^{-1/\theta} = \kappa C_U(\delta/\kappa). \tag{9}$$

When a firm switches its assembly location from D to F, the part cost κ induces a discrete drop in the unconstrained domestic part share from $\chi_U^D(\delta) = \chi_U(\delta\kappa)$ to $\chi_U^F(\delta) = \chi_U(\delta/\kappa)$. This is associated with an unconstrained relative cost:

$$\tilde{C}_U(\delta) = \frac{C_U^F(\delta)}{C_U^D(\delta)}.$$

This relative cost $\tilde{C}_U(\delta)$ is increasing from κ^{-1} to κ as δ goes from 0 to ∞, and is equal to 1 when $\delta = 1$. Thus, a switch in assembly from D to F lowers the unconstrained cost whenever $\delta < 1$ and conversely raises that unconstrained cost whenever $\delta > 1$. A higher part trade cost κ magnifies those cost differentials—as well as the underlying responses of the domestic and Foreign part shares.

[13] Throughout, we abstract from a normative analysis that would weigh the employment and producer surplus gains associated with higher part and assembly production against the distortions induced by the RoO.

3.2.2. Compliance and assembly location

A firm δ chooses between compliance with assembly in D (CD), and non-compliance with assembly in either D (NCD) or F (NCF). The associated cost is:

$$C(\delta) = \begin{cases} C_U^D(\delta) & \text{CD-unconstrained } (\delta \geq \delta^{D\circ}), \\ C^D(\chi_R, \delta) & \text{CD-constrained } (\delta < \delta^{D\circ}), \\ \tau^D C_U^D(\delta) & \text{NCD}, \\ \tau^F \omega^F C_U^F(\delta) & \text{NCF}. \end{cases} \tag{10}$$

The firm will choose the option with the lowest cost:

$$\min\left\{C_U^D(\delta), C^D(\chi_R,\delta), \tau^D C_U^D(\delta), \tau^F\omega^F C_U^F(\delta)\right\} = C_U^D(\delta)\min\left\{\tilde{C^D}(\chi_R,\delta), \tau^D, \tau^F\omega^F\tilde{C}_U(\delta)\right\},$$

where the two CD cases (unconstrained and constrained) are combined into a single case using the relative cost of compliance in D:

$$\tilde{C}^D(\chi_R,\delta) = \begin{cases} \frac{C^D(\chi_R,\delta)}{C_U^D(\delta)} & \delta < \delta^{D\circ}, \\ 1 & \delta \geq \delta^{D\circ}. \end{cases}$$

Note that $\tilde{C}^D(\chi_R,\delta) = \tilde{C}(\chi_R,\delta\kappa)$, so it has exactly the same shape of old $\tilde{C}(\chi_R,\delta)$ with a lower bound of 1 when $\delta \geq \delta^{D\circ}$.

The choice of compliance and assembly location thus leads to a similar threshold condition for the relative cost of compliance $\tilde{C}^D(\chi_R,\delta)$. The firm chooses compliance (CD) whenever that cost is below the thresholds τ^D and $\tau^F\omega^F\tilde{C}_U(\delta)$.[14] The only complication relative to the previous case of intra-NAFTA assembly relocation is that the threshold for Foreign assembly, $\tau^F\omega^F\tilde{C}_U(\delta)$, now depends on δ (due to the impact of the part trade cost κ). But critically, this threshold does not depend on the RoO χ_R. For a given firm δ, both thresholds are fixed. If $\tau^D < \tau^F\omega^F\tilde{C}_U(\delta)$ then NCD dominates NCF and the firm will not relocate assembly to F regardless of the level of the RoO χ_R. Its tradeoff between compliance and non-compliance is very similar to the one we previously analyzed when assembly location was exogenously fixed in D. However, when that inequality is reversed, then NCF dominates NCD for that firm. This will be the case for all firms with δ below the cutoff δ^{DF} such that $\tilde{C}_U(\delta^{DF}) = \tau^D/\tau^F\omega^F$.[15] As the RoO χ_R increases and the relative cost of compliance $\tilde{C}^D(\chi_R,\delta)$ rises above the threshold $\tau^F\omega^F\tilde{C}_U(\delta)$, then the firm chooses non-compliance in F, and relocates its assembly there. This induces a drop in the domestic part share that is magnified relative to the case of a fixed assembly location in D. Instead of dropping back to $\chi_U^D(\delta)$, the firm's domestic part shares drops down to $\chi_U^F(\delta)$. This latter domestic part share when assembly is in F can be substantially below the former domestic part share when assembly is in D. The gap between those two part shares is higher when κ is higher and for firms with lower δ.

We now illustrate those cost alternatives and sourcing decisions for the case of two firms in Fig. 6.[16] Firm 1 with the lower foreign part cost (purple, $\delta_1 = 0.6$) has a δ *below* the δ^{DF} cutoff so that $\tau^D > \tau^F\omega^F\tilde{C}_U(\delta_1)$: NCF dominates NCD for this firm (purple line *below* the τ^D line). Firm 2 with the higher foreign part cost (orange, $\delta_2 = .8$) has a δ *above* the δ^{DF} cutoff so that $\tau^D < \tau^F\omega^F\tilde{C}_U(\delta_2)$: NCD dominates NCF for this firm (green line *above* the τ^D line). When the RoO χ_R is very low, $\chi_U^D(\delta_i) > \chi_R$ for both firms and compliance with the RoO is costless: $\tilde{C}^D(\chi_R,\delta_i) = 1$. Both firms therefore choose compliance, CD-unconstrained. As χ_R rises, the rule becomes binding for firm 1 as $\tilde{C}^D(\chi_R,\delta_1)$ rises above 1 when χ_R reaches about 20%. Firm 1 still complies but is constrained, CD-constrained. When χ_R rises above 40%, $\tilde{C}^D(\chi_R,\delta_2)$ rises above 1 and firm 2 is also constrained (CD-constrained). When χ_R reaches about 50%, $\tilde{C}^D(\chi_R,\delta_1)$ rises above $\tau^F\omega^F\tilde{C}_U(\delta_1)$ and firm 1 switches to NCF and relocates assembly from D to F. Lastly, when χ_R rises above 80%, firm 2 chooses non-compliance but without relocating assembly to F (NCD).

Fig. 6 also illustrates how domestic part sourcing is affected with assembly relocation from D to F: notice that the switch from CD to NCF for firm 1 at χ_R around 50% is associated with a drop in domestic sourcing substantially below its previous unconstrained sourcing choice when assembly was in D (bottom panel). This drop from $\chi_U^D(\delta) = \chi_U(\delta\kappa)$ to $\chi_U^F(\delta) = \chi_U(\delta/\kappa)$ is magnified for higher values of the part trade cost κ.

In contrast the switch from CD to NCD for firm 2 at χ_R around 80% is associated with a drop in domestic sourcing back to its previous unconstrained sourcing choice. In the following section, we show how this magnified drop in domestic part sourcing associated with non-compliance and assembly relocation to F can generate a Laffer curve that is not only backward bending, but one whose backward bending portion induces domestic part sourcing *below* its initial level when there is no rule of origin.

[14] Allowing for another assembly location just adds another threshold. For example, adding the assembly location R inside the RTA adds the threshold $\tau^R\omega^R$ we previously derived. In this case with 3 locations (D, R, F), the part shares χ refer to the regional part shares sourced from both D and R.

[15] Recall that $\tilde{C}_U(\delta)$ is increasing.

[16] This figure is the endogenous assembly analog to Fig. 1. We use the same parameters used are $\theta = 4$, $\tau^D = 1.05$; The additional parameters are $\tau^F = 1.2$, $\omega^F = 1$, $\kappa = 1.15$.

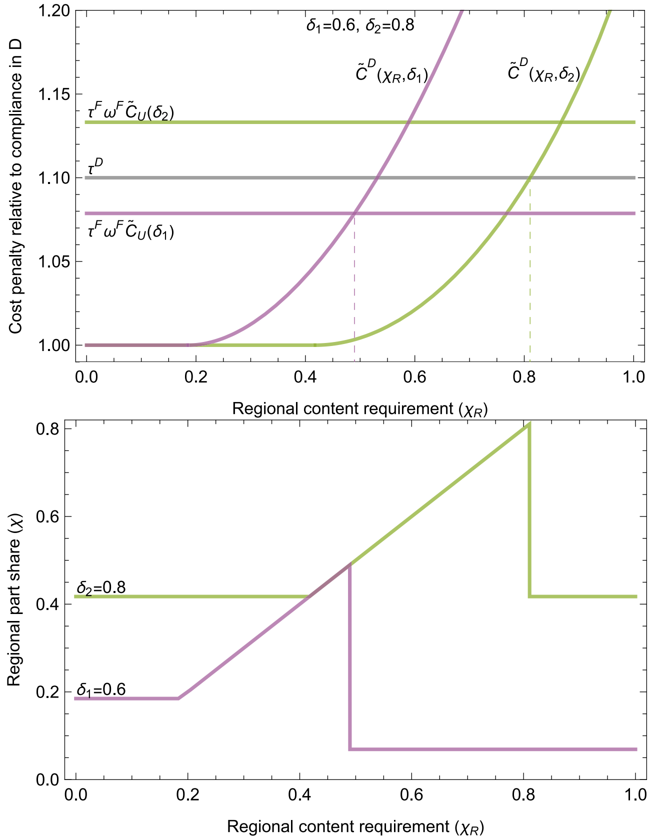

Fig. 6. Compliance cost and sourcing decision with assembly option in F.

3.2.3. RoO Laffer curve with endogenous assembly

Fig. 7 graphs the aggregate part share $X(\chi_R)$ Laffer curves for different values of the part trade cost κ. The non-changing parameters are $\theta = 4$, $\tau^D = 1.1$, $\tau^F = 1.2$, $\omega^F = 1$ (as in the previous figure); and we set the variance of the log-normal draws for δ to $\sigma = 0.2$ in all cases. For each case of κ, the mean (μ) of the δ-draws is shifted down by $\ln(1/\kappa)$. This means that when assembly in F is not an option, the effect of κ on all outcome variables is exactly offset by the shift in δ (because then only the product of κ and δ matters). So regardless of κ, the blue curve always shows the outcome when assembly in F is ruled out. This is the same Laffer curve used earlier in the paper. Fig. 7 highlights how the possibility of assembly relocation to F shifts down the response of the aggregate part share $X(\chi_R)$, and how this response is magnified for higher values of κ. As we previously described, this downward shift is driven by the response of a firm's part share when it relocates assembly from D to F (see bottom panel of Fig. 6 for firm 1), which is magnified for higher κ.

When κ is below 1.2, all firms still choose to assemble in D and comply with the RoO (CD) when it is low enough. The Laffer curves for low χ_R thus overlap with the old Laffer curve with exogenous assembly in D. But when $\kappa = 1.2$ (green curve), the downward shift due to the relocation of assembly is strong enough for a more restrictive RoO to induce a *lower* aggregate part share than that initial level when there is no rule of origin ($\chi_R = 0$). In other words, the green Laffer curve ends up below the dashed line for high enough χ_R. When κ is above 1.2, some firms with low δ choose to assemble in F even when there is no rule of origin. This why the Laffer curve at $\chi_R = 0$ is shifted down. This is barely noticeable when $\kappa = 1.25$ (purple curve), though the downward shift in the Laffer curve for more restrictive RoOs is much more pronounced. The downward shift at $\chi_R = 0$ is much more noticeable when $\chi_R = 1.3$ (red curve). In this last case with the highest part trade cost, the negative impact of increases in the RoO χ_R on the aggregate part share – driven by the set of firms that choose NCF and relocate assembly to F – always dominates the positive impact on the part share driven by the set of firms that choose CD-constrained and raise their part share to comply with the higher RoO. In this case, the Laffer curve is no longer hump-shaped and a more restrictive RoO can only lead to decreases in the aggregate part share.

4. Calibration for North American auto supply chains

The existence of a hump-shaped relationship between the content requirement and the realized regional content share holds under a wide range of parameters. But as illustrated in Appendix Figure C.1, the shape and peak of the curve varies considerably as

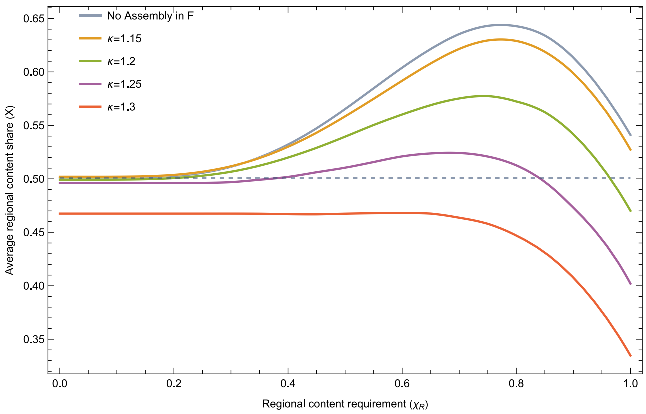

Fig. 7. RoO Laffer curve with option to relocate assembly.

Table 1
Counts and medians of NAFTA parts cost shares and tariff indexes.

	Cars				Light trucks			
Assembly Country	Count carlines	Median λ (in %)	Count models	Median τ	Count carlines	Median λ (%)	Count models	Median τ
Canada	65	70	36	1.02	4	80.50	4	1.10
Mexico	139	60	59	1.01	19	88.00	15	1.20
USA	377	62	176	1.01	46	75.00	37	1.01

Note: Medians for North American shares from AALA data, 2011–2019. τ is the tariff index (Section 4.2), obtained from IHS data, 2011–2018. Ford "Fusion 2.5L, (Auto)" is a carline; "Ford Fusion" is a model.

we alter the parameters. In this section, we discipline the parameters with data from the North American automotive industry. This yields an empirically calibrated Laffer curve for the industry. Thus, we can quantify the impact of the stricter content requirements in the new USMCA relative to the old NAFTA agreement for regional part sourcing. The Laffer curves we compute also provide quantitative predictions for all other RoO levels. Given that these curves are hump-shaped, the RoO level associated with its peak is of particular interest: any stricter content requirement would then reverse the direction of the impact on part sourcing.

Ultimately, the impact of any RoO policy should incorporate the vehicle production adjustment associated with any induced part-sourcing change and associated tariff penalties. This delivers quantitative predictions for the impact of the RoO on both part and vehicle production and the associated employment. In this section, we focus on the predictions for part sourcing that are derived by our theoretical model. In the following section, we add some theoretical structure to extend these predictions to the impact on part and vehicle production. And for now, we also focus on the baseline model, where the location of assembly is fixed. This can be justified as a medium-run policy analysis, in that firms can adjust the sources of parts but cannot change the location of their final assembly plants. After we introduce vehicle production adjustments in the next section, we also extend our simulation to incorporate assembly relocation.

In our baseline model with fixed-assembly in Section 2, there are just four parameters – μ, σ, θ, and τ – that need to be calibrated. μ and σ, along with the log-normal parametrization, determine the distribution of the relative cost δ; and together with θ and τ, they determine the equilibrium distribution of the regional part shares across producers. We therefore use data on the observed part sourcing decisions, along with data we construct to capture tariff penalties, to derive the simulated method-of-moments estimates of the parameter values of the δ distribution (namely μ, σ), along with two other parameters that we add to allow for additional heterogeneity in some unobserved data components.

The appeal of our focus on the auto industry comes partly because it figured centrally in the negotiation of the new USMCA agreement. The other appealing feature of this sector is the availability of a rich data set on a core variable in the model, λ, the share of parts costs sourced within the RTA. The *American Automobile Labelling Act* (AALA) provides annual reports showing the cost share for North American partners for all models of cars and pickup trucks sold in the US and Canada.

We use a second source of data on cars and trucks, the IHS Markit automotive sales module, to obtain the market destinations of car models made in North America. As explained in Section 4.2 below, this data is needed to construct an index of τ that takes into account the fact that substantial shares of vehicles sales are not subject to the RoO tariff penalty because they are not exported within North America (such as domestic sales and exports outside North America). Combining these two data sets allows us to measure λ and τ at the level of a "carline", a unit that always has the brand, model, and plant location, and often has additional detail on engine size or body type. We fix those carlines as the decision-making entities for part sourcing—labeled as firms in our theoretical model.

Table 1 provides a few statistics from the AALA data. It shows, for each North American assembly country, the number and median parts cost share (λ in the model) for cars (including Sport Utility and Multi-Purpose Vehicles such as minivans) and light

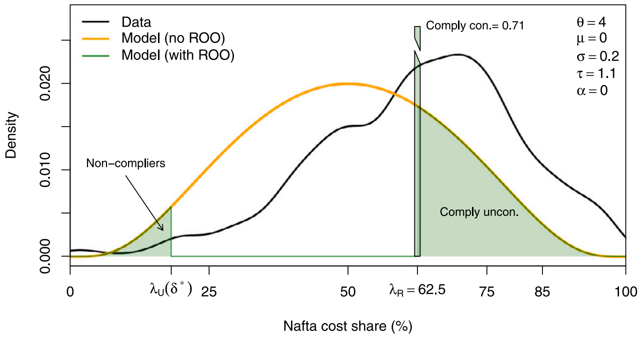

Fig. 8. Density of λ: model vs data.

trucks (pickup trucks and vans). Two features are notable. First, the median part costs shares (λ) has its lowest value at 60%, which means that the majority of cars and trucks in the three countries are compliant at the NAFTA RCR. Indeed, note that the regional part cost shares (λ) are lower than full regional content that counts towards meeting the RCR because the latter include assembly costs. Since assembly cost shares are on average 15%, the 70% parts cost share for Canadian cars is sufficient for the median car to meet the new USMCA RCR. Within countries, light trucks have higher NAFTA parts content and are more likely to be assembled in the US.

We also report the median tariff penalty (τ). As we describe in further detail in Section 4.2, the tariff penalties for Canadian- and Mexican-assembled vehicles are strongly influenced by the 2.5% (for cars) and 25% (for truck) MFN rates that would be applied to exports to the United States that do not comply with the RoO. The tariff penalties are substantially lower for the US-assembled vehicles because so many of those are not exported and thus unaffected by any RoO. The higher λ for trucks supports the model prediction that compliance rates increase with τ.

4.1. Initial comparison of model and data densities

We begin by considering the model as specified in the theory section, as this will help identify what extensions we need to make in order to achieve a reasonable fit to the observed distribution of NAFTA costs shares. The model predicts a firm's (carline) part share χ as a function of the RoO, expressed as the required share of parts χ_R. While this facilitates exposition, the primary NAFTA rule is a Regional Content Requirement (RCR), expressed in terms of the share of total cost incurred within the region.

We match the moments for the simulated parts cost shares (λ) to the observed AALA data between 2011 and 2019, a period when the actual RCR was 62.5%. Given an RCR, the parts costs requirement is given by

$$\lambda_R = \frac{\mathrm{RCR} - \alpha}{1 - \alpha}, \tag{11}$$

where α denotes the share of final assembly in total costs. First, consider the distribution of domestic parts costs shares for carlines that are unconstrained by the RCR. Recalling that $F(\delta)$ is the CDF of the foreign cost advantage – with $\ln \delta \sim \mathcal{N}(\mu, \sigma)$ – the cumulative density of λ is given by (see Appendix section B for detailed derivations):

$$G(\lambda) = \Phi\left(\frac{\ln(\lambda/(1-\lambda)) - \theta\mu}{\theta\sigma}\right). \tag{12}$$

Since the log odds ratio of λ is normally distributed for unconstrained carlines, the maximum likelihood estimates of $\theta\mu$ and $\theta\sigma$ are given by the mean and standard deviation of $\ln(\lambda/(1-\lambda))$. From this, we can see that the parameters μ and σ characterizing the heterogeneity of δ are not separately identifiable from θ when all carlines are unconstrained. For this reason, we do not attempt to estimate θ and instead fix it at $\theta = 4$.[17]

Fig. 8 plots the density of parts costs shares $g(\lambda)$, from the distribution (12) in orange. The parameters are the same as in the baseline case of our theory section ($\theta = 4$, $\mu = 0$, $\sigma = 0.2$, $\tau = 1.1$). For this figure we choose the regional content requirement to equal the parts cost share requirement (λ_R) so we set $\alpha = 0$. With a binding rule of origin, the model predicts a distribution of cost shares λ, depicted in green in Fig. 8, that is very different from the unconstrained orange density. In this simple setup of the model, there is a single threshold δ^* (such that $\tilde{C}(\chi_R, \delta^*) = \tau$) beyond which carlines begin to comply with the rule. This set of parameters implies that 71% of carlines have a δ high enough to choose to comply exactly at $\lambda_R = \mathrm{RCR} = 62.5\%$ as shown on the spike in the figure. The green shaded density shows the carlines that have high costs of domestic inputs (non-compliers) or such low costs that they choose NAFTA shares above the requirement.

The black line in Fig. 8 depicts the empirical distribution of regional shares for carlines produced in Canada, Mexico or the USA, pooled over the years for which we have data and for which the RCR is 62.5%, that is 2011–2019. Two predictions of the

[17] Appendix D provides the rationale for choosing $\theta = 4$.

simple model are at odds with what we observe in the AALA data: (1) the "hole" in the λ distribution between $\lambda_U(\delta^*) = 18.2\%$ and $\lambda_R = \text{RCR} = 62.5\%$, (2) the spike at λ_R.[18]

As in Eaton et al. (2011), the basic model predicts stronger partitioning of firms into decision regimes relative to what is observed in the data. In that paper, the problem is that firms do not comply with strict hierarchies across export destinations that the single-heterogeneity model predicts. The authors address this problem by introducing additional realistic dimensions of heterogeneity in the form of idiosyncratic entry cost and demand shocks. In that spirit, our calibration departs from the unrealistic assumption that all carlines have the same τ and α. Furthermore, we take into account measurement error by simulating the observed λ to equal the model-generated λ with measurement error. These three generalizations of the model result in it no longer predicting the large empty region followed by bunching exactly the threshold for compliance. Of the three, the heterogeneous τ is the most complex, so we address that first in the next subsection.

4.2. Measurement of τ index heterogeneity

Carlines assembled in North America sell to destination countries d which we group in three sets: the assembly location ℓ, countries other than ℓ in the North America RTA, $\mathcal{R}$ and other foreign countries outside the agreement $\mathcal{F}$. Only exports to $\mathcal{R}$ are affected by the RoO. For each carline, we define τ as the cost penalty that induces the same reduction in profits as being hit with MFN tariffs ($\tau_d > 1$) on the non-compliant vehicles exported to $\mathcal{R}$. τ therefore varies with the dependence of each carline's sales on different destinations d. We show in Appendix F that, for constant price elasticity of demand η, the τ index can be written as

$$\tau = \left(\frac{1 + \sum_{d\in\mathcal{R}} (A_d/K)\tau_d^{1-\eta}}{1 + \sum_{d\in\mathcal{R}} (A_d/K)} \right)^{1/(1-\eta)}, \tag{13}$$

where the A_d are location-specific demand shifters. $K \equiv A_\ell + \sum_{d\in\mathcal{F}} A_d \tau_d^{1-\eta}$, accounts for all sales outside $\mathcal{R}$ that are unaffected by the RoO. It therefore does not depend upon RoO compliance. A_d potentially incorporates carline-specific demand in each market, transport costs, and a d-specific CES price index.

The next step is to calibrate the parameters A_d/K in terms of observables. Let r_d denote the ratio of destination $d \in \mathcal{R}$ sales relative to sales in all $d \notin \mathcal{R}$ for a given carline. Under CES monopolistic competition, r_d is given by

$$r_d \equiv \frac{p_d q_d}{p_\ell q_\ell + \sum_{d\in\mathcal{F}} p_d q_d} = \frac{A_d}{A_\ell + \sum_{d\in\mathcal{F}} A_d \tau_d^{1-\eta}} = \frac{A_d}{K}, \tag{14}$$

where we assume that, in the observed data, firms comply with the rule of origin and hence do not pay the MFN tariff. This assumption is justified by the very high level of actual preference utilization rates (PUR) under NAFTA. The true PUR for US-made cars entering Canada is 97% in 2019 (before the change in the regional content requirement in 2020).[19] Substituting (14) into (13), our empirical implementation of the τ index becomes

$$\tau = \left(\frac{1 + \sum_{d\in\mathcal{R}} r_d \tau_d^{1-\eta}}{1 + \sum_{d\in\mathcal{R}} r_d} \right)^{1/(1-\eta)}. \tag{15}$$

In order to measure r_d, we use IHS Markit sales data. This is the same source as Head and Mayer (2019). It provides, for every carline and year combination, the total number sold from a particular assembly plant to a particular final market. For each carline assembled in North America, we use the sales volume ratios, $q_d/(q_\ell + \sum_{d\in\mathcal{F}} q_d)$, as a proxy for the destination-priced sales ratios r_d. To match our use of AALA data from 2011 to 2019, we calculate the τ index starting in 2011 and continuing to the most recent year for which we have data, 2018. This yields 1758 observations for carlines assembled in North America.

We expect r_d to vary across carlines due to heterogeneity in demand as well as differences in transport costs. Additionally, the MFN tariffs vary substantially by country and vehicle type: The US imposes a 25% tariff on light trucks but only 2.5% on passenger cars; Mexico's tariffs go up to 35% for cars and 23% for trucks; Canada charges 6% on both types of vehicles.

Fig. 9 plots the estimated densities of τ separated by assembly location: Canada (red), Mexico (green), and the USA (blue). Our calculation of τ assumes $\eta = 4$, a value supported by our review of the literature on demand for autos.[20] Most of the density for both Canada and Mexico lies around a mode near 1.025, the US MFN on passenger cars. However, there is a second mode for Mexico near 1.23 corresponding to pickup trucks and commercial vehicles mainly exported to the US where imports of this vehicle type are subject to the 25% MFN duty. Note that US cars have the lowest τ index, despite the higher MFN tariffs in Canada (6%) and Mexico (35%). This is because of the relatively low shares of US-assembled cars destined to the NAFTA trade partners. The black line pools observations for carlines assembled in all three countries. The distributions turn out to be very irregular and are hard to fit with simple parametric densities. For example, we show the very poor fit of a log-normal distribution for the pooled data.

[18] The latter spike is shown as a broken bar since its true height would be far above the modes of the other densities.

[19] The very high PUR observed for autos in NAFTA is in keeping with the finding of Krishna et al. (2021) that larger firms are more able to overcome fixed documentation costs and learn over time how to comply with RoOs. In this case, the major automakers have been complying with RoOs since the 1965 Auto Pact.

[20] Appendix D provides the relevant references.

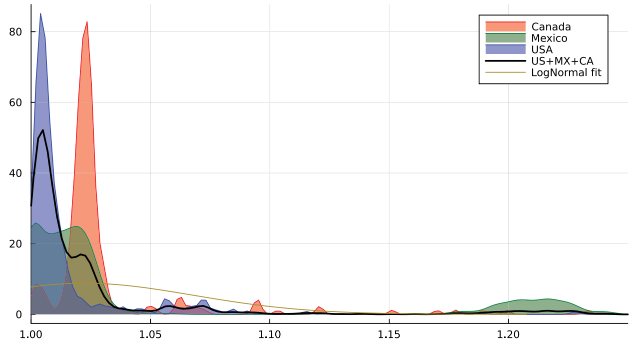

Fig. 9. Distribution of τ index across models assembled in NAFTA.

4.3. Estimating the heterogeneity distribution parameters

There are four parameters to be estimated: the μ and σ from the log-normal δ distribution, and the concentration parameters for α heterogeneity and measurement error. We do this via simulated method of moments.

Each carline j in the simulation is characterized by a $\{\delta_j, \tau_j, \alpha_j\}$ vector. The number of draws takes the number of carlines in the AALA data, and multiplies it by 100 in order to have a set of draws large enough to resemble a continuum. The δ_j are drawn from a log-normal distribution with parameters μ and σ. The τ_j are sampled from the distributions shown in Fig. 9. The shares of assembly in total costs, α_j, are drawn from a Beta distribution with mean $\bar{\alpha}$ and concentration parameter ν_α.[21] This mean-concentration parametrization facilitates calibration.

A variety of sources point to a cost share for parts of approximately 85%, so we set the mean assembly share to be $\bar{\alpha} = 0.15$. Appendix D provides the data sources for this calculation and the other non-estimated parameters.

With the $\{\delta_j, \tau_j, \alpha_j\}$ draws, we compute the vector of compliance decisions and optimally chosen regional share of parts costs λ_j as follows.

1. For unconstrained carlines, $\lambda_{Uj} = \chi_{Uj}(\delta_j)$ (the share of parts costs is equal to share of parts).
2. For compliant-constrained carlines, compute λ_j by transforming the common RCR into a carline-level $\lambda_{Rj} = (\text{RCR}-\alpha_j)/(1-\alpha_j)$ (an adaptation of Eq. (11) to the case of heterogeneous assembly cost shares).
3. Eq. (5) maps λ_{Rj} from step 2 and δ_j to obtain χ_{Rj}, the carline-specific required regional parts share.
4. Compute the cost of compliance, $\tilde{C}(\chi_{Rj}, \delta_j)$, using Eq. (6) and compare it to τ_j to obtain the optimal compliance decision for each carline. The chosen parts cost share is

$$\lambda_j = \begin{cases} \lambda_{Rj} & \text{if} \quad \tilde{C}(\chi_{Rj}, \delta_j) < \tau_j \text{ and } \lambda_{Uj} < \lambda_{Rj}, \\ \lambda_{Uj} & \text{otherwise.} \end{cases} \tag{16}$$

5. To allow for measurement error, draw the simulated parts cost share, λ_j^{sim}, from a Beta distribution with mean λ_j (step 4) and concentration ν_λ.[22]

The distribution of simulated parts costs shares (λ_j^{sim}) is then compared to the distribution of North American parts cost shares that we observe in the AALA data (λ_j^{data}). We compute kernel densities of each of the two distributions, round those to the nearest percentile, and compute the L_2 norm between the 100 centiles. We search for our set of parameters the values which minimize the L_2 norm between the density of the data and the density of the (measurement error augmented) model.[23]

The blue line in Fig. 10(a) plots the density of λ_j^{sim}. The black line in the figure depicts λ_j^{data} (the same kernel density shown in Fig. 8). The high quality of the fit is revealed by the proximity of the two densities.

To provide external validation, we compared data on preference utilization rates (PUR) for cars (97% for Canadian imports from the US) to those that emerge from the simulation. The calibrated model predicts 24.4% of carlines comply constrained (CC) and 61.4% comply unconstrained (CU). As those rates sum to 86%, we see that the calibrated model comes in reasonably close to an important untargeted moment.

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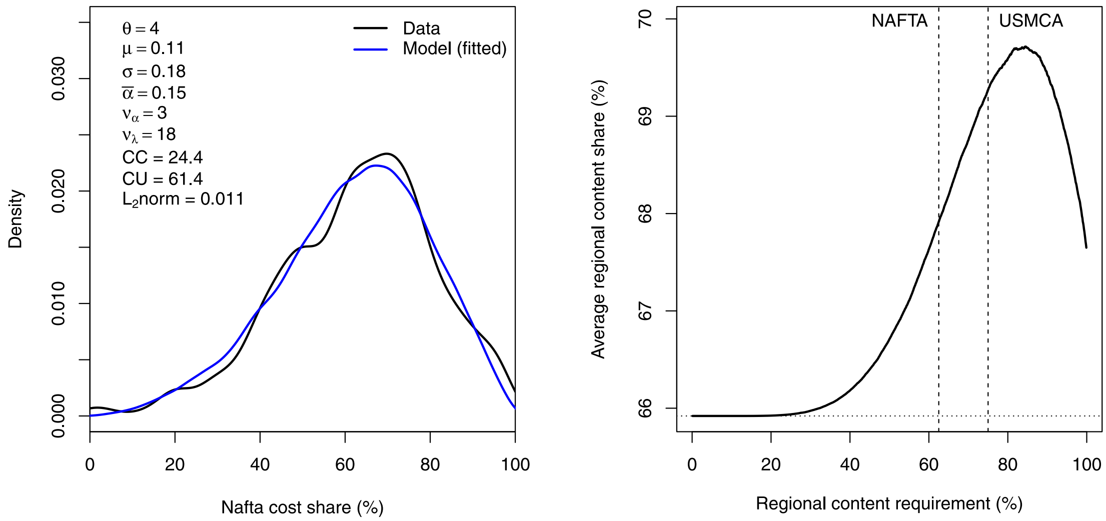
[21] The Beta distribution constrains the α_j to stay within 0 and 1. The concentration parameter, ν_α, relates to variance as $\nu = \bar{\alpha}(1-\bar{\alpha})/\text{var}(\alpha) - 1$. The correspondence back to the standard Beta shape parameters is $a = \bar{\alpha}\nu_\alpha$ and $b = (1-\bar{\alpha})\nu_\alpha$.

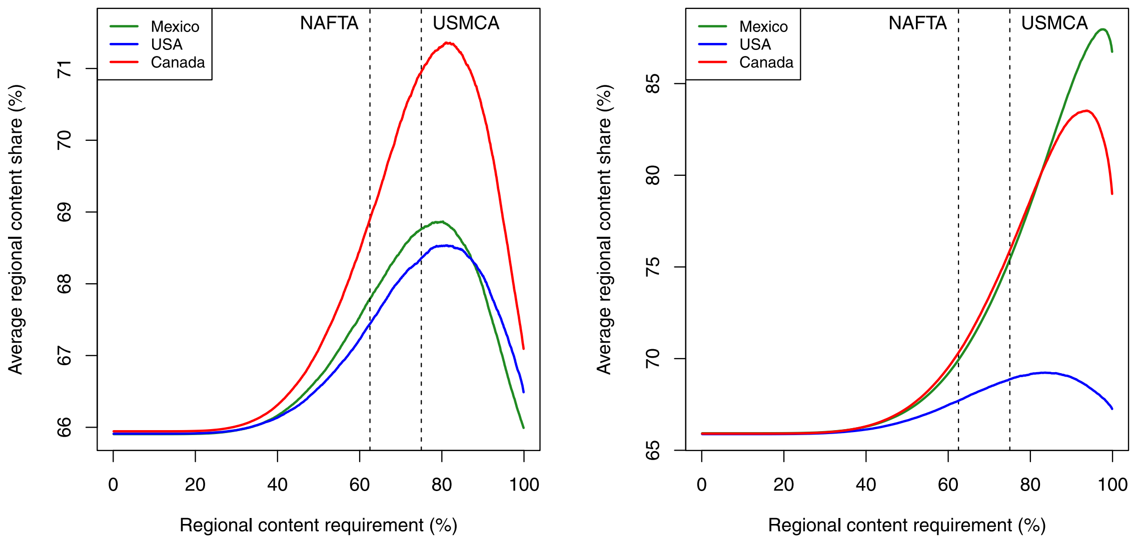
[22] Among the sources of error are the AALA exemption for reporting Mexico content if it is below 15%. Additional measurement error comes from rounding which the law permits to the nearest 5%. The error also captures deviations from the continuum assumption in the model. Since many parts have non-negligible cost shares, a firm that intends to "just comply" will in fact be observed to over-comply depending on the share of the last part.

[23] The L_2 norm is also referred to as the Euclidean distance and is given by $\sqrt{\sum_{i=1}^{100}(\lambda_i^{\text{sim}} - \lambda_i^{\text{data}})^2}$, where i are centiles. The search iterates over a grid of 366,912 potential parameter values of $\{\mu, \sigma, \nu_\alpha, \nu_\lambda\}$.



(a) λ densities (b) regional part cost share

Fig. 10. Fitted density and RoO Laffer curve.



(a) passenger cars (b) light trucks

Fig. 11. RoO Laffer curves for part cost shares.

4.4. Laffer curve for part share

Fig. 10(b) plots the calibrated Laffer curve, mapping from content requirements (RCR) to realized content shares (RCS). The content share of an individual carline j comprises the share of costs coming from domestic assembly, α_j, plus the component share of total costs, $1 - \alpha_j$, multiplied by the share of parts costs that are procured within the region, λ_j. The aggregate RCS is the mean of $\alpha_j + \lambda_j(1 - \alpha_j)$ across all the simulated carlines.

The Laffer curve in Fig. 10(b) begins at about 66% when there is no rule of origin. Increases in the RCR have no effect until they reach about 21%. This is driven by a combination of the local assembly costs and the unconstrained preferences for regionally-sourced parts. For the estimated parameters, the Laffer curve peaks at an RCR of 84%. Note that the realized content share would be much lower at just 70%, because many carlines would then choose non-compliance with that rule. Although the 62.5% rule, under the original NAFTA, was on the upward sloping part of the Laffer curve, the visual impression of a steep upward slope is the consequence of the narrow vertical range. Raising the RCR by 20% (75/62.5 − 1) increases the RCS by only 2% (69.3/67.9 − 1).

Fig. 10(b) draws the Laffer curve for North America taken as a whole and also combines all light vehicles. This raises two interesting questions. Given the very high US market orientation of Mexican and Canadian plants – as reflected in their high median τ in Table 1 – how different are their Laffer curves from that of the US? The tariff penalties also vary significantly between cars and light trucks. How do those differences quantitatively affect the Laffer curves?[24]

Fig. 11 shows the separate Laffer curves for Canada (red), the US (blue), and Mexico (green) in panel (a) for cars and in panel (b) for light trucks. The fact that the US market is the major destination for most trucks combined with having a 25% tariff pushes the Laffer curves in panel (b) to much larger levels of regional content share than in panel (a). Those curves are also shifted right, showing that manufacturers are willing to comply with much larger RCR levels for trucks than for cars. When comparing Canada with Mexico, the ranking of the curves depends on the product considered, reflecting the fact that Canadian-made car sales are much more concentrated in the US market than Mexican-made ones. This relationship is inverted for trucks. Non-compliance with the RoO is clearly less costly for US-assembled cars (and even more so for US-made trucks), since this involves paying high MFN in Canada and Mexico, but applied to a small fraction of sales.

5. Laffer curves with vehicle production adjustment

In our theoretical derivations, we derived predictions for the unweighted share of parts sourced within the regional agreement (X). This is as far as we can go without imposing further structure on demand, market structure, and the relative employment weights in assembly versus parts. However, by adding a small set of additional assumptions, we can derive and aggregate – for any simulated RCR – the induced changes in prices, vehicle output, and employment. Unless a RoO leaves all carlines unconstrained, it will result in cost-associated prices increases for vehicles, and hence lower vehicle demand. Even from a wholly protectionist perspective, a stricter RoO policy that raises the average part share by a given percentage – because it is associated with an even greater percentage decrease in average vehicle production – would lower part production and employment. And presumably, a protectionist policymaker would also want to weigh the negative consequences of lower vehicle production and associated assembly employment decreases, even if it raises production and employment in the part sector. We do not analyze the policymaker's optimal choice of a RoO. This would involve choosing weights for the production and employment response in parts and assembly (possibly moving in opposite directions)—as well as for consumer surplus. Instead, we report how a simulated RoO affects all of those welfare components separately.

5.1. *Fixed assembly location: Intensive margin*

For now, we maintain our "medium-run" assumption of fixed assembly location. We impose the additional assumptions of CES demand and monopolistic competition. Those are the same assumptions that we used to compute the average tariff penalty τ_j for a carline across destinations. Using "exact hat algebra" in the same vein as Dekle et al. (2007), we aggregate carline-j level changes for any simulated RoO relative to the case of no content requirement (RCR at 0%). For any variable of interest, this aggregates into a Laffer curve in percentage change.

Those Laffer curves are shown in Fig. 12 for the three assembly countries as separate rows and for cars and trucks as separate columns. The black curves show similar Laffer curves for the average part share as the ones from Fig. 11. But now, we show the average *change* $\hat{X}^D$ for the percentage change in the carline-j part shares $\hat{\chi}_j = \chi_j/\chi_j^\circ$, where χ_j° is the carline-j part share when the RCR is at 0%.[25] We use the superscript D to denote an aggregation over "domestic" carlines assembled in $D \in \{\text{CAN}, \text{MEX}, \text{USA}\}$. This distinction will become relevant once we allow for assembly relocation in the next section.

In all six cases depicted in Fig. 12, we see that the slope of the Laffer curves for the average change in the part share in black are very similar to the ones depicted in Fig. 11 corresponding to the part shares in levels. We now incorporate the response of vehicle production to the RoO. We refer to this as the intensive margin, given that the location of that production (assembly) remains fixed.

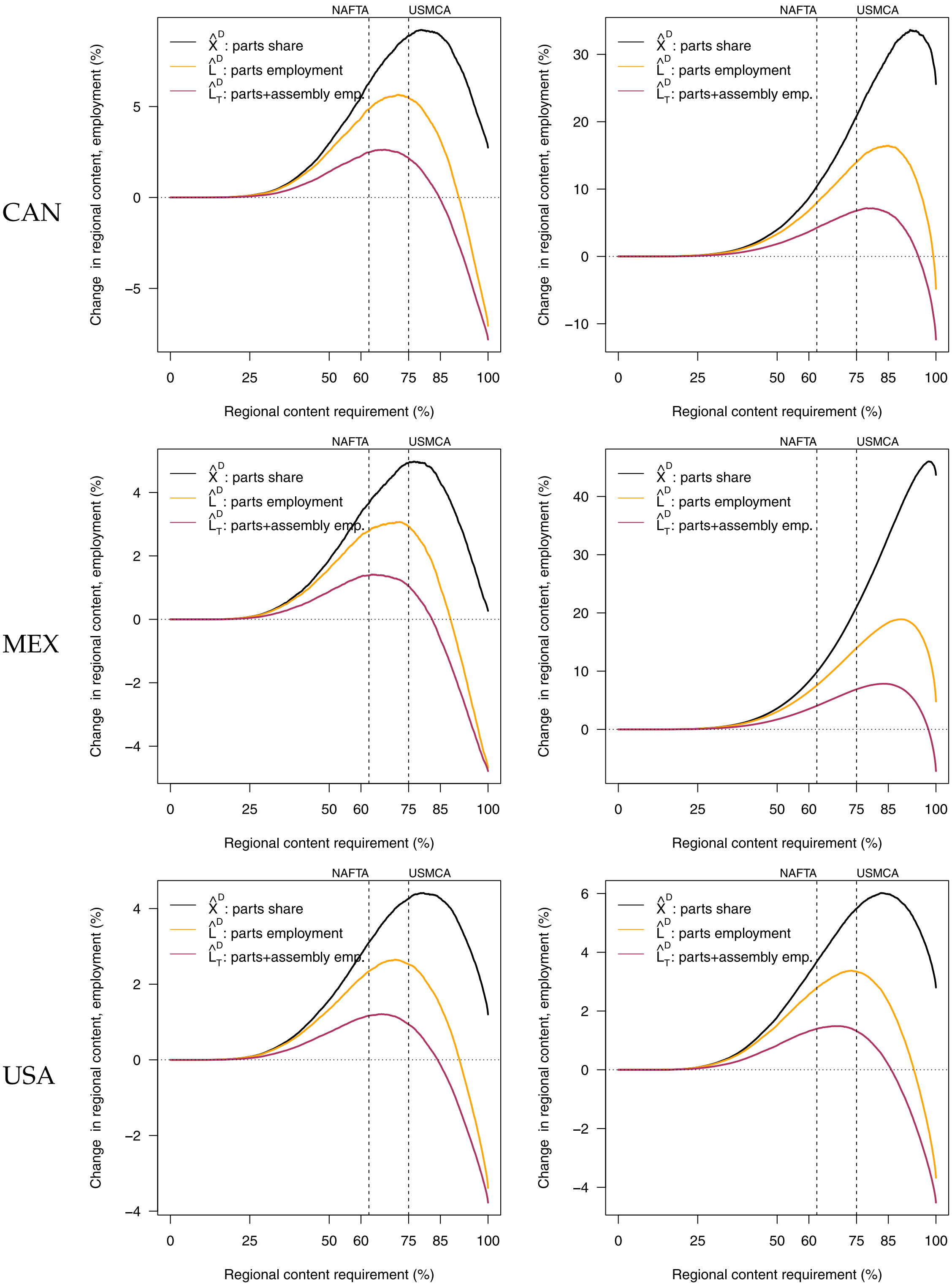
In Appendix E, we detail how we use the carline's compliance cost $\tilde{C}(\chi_{Rj}, \delta_j)$ (when RoO-compliant), the tariff penalties τ_{dj} across destinations (when non-compliant), the assembly cost share α_j, and the assumption of CES demand with constant markups (monopolistic competition) to calculate the percentage change in the carline's production volume $\hat{Q}_j = Q_j/Q_j^\circ$. The change in part production induced by the RoO combines the part share and production volume changes: $\hat{L}_j = \hat{\chi}_j\hat{Q}_j$. We denote this as the part employment change, incorporating an additional assumption that part employment changes proportionately with part production. Similarly, we assume that assembly employment changes proportionately with the production volume: $\hat{L}_{Aj} = \hat{Q}_j$. We then aggregate these employment changes $\hat{L}^D$ and $\hat{L}_A^D$ across all carlines assembled in $D \in \{\text{CAN}, \text{MEX}, \text{USA}\}$, under the assumption that the initial employment shares across all carlines when there is no RoO (RCR at 0%) are uncorrelated with the $\{\delta_j, \tau_j, \alpha_j\}$ calibrated draws.[26] And lastly, we use the observed ratio of assembly to part employment under NAFTA (RCR=62.5%) to combine the part and assembly employment changes into a total automotive industry employment change $\hat{L}_T^D$ by country of assembly D. All the computations for these aggregations are provided in Appendix E.

The Laffer curves for the part employment changes ($\hat{L}^D$ in orange) and combined part and assembly employment ($\hat{L}_T^D$ in red) are also plotted in Fig. 12. Adding the negative vehicle production response to the RoO substantially shifts down the employment

[24] The high 25% US tariff on light trucks is a legacy from the 1964 "Chicken war" with France and Germany.

[25] Throughout, we use the superscript $\circ$ to denote an outcome when the RCR is at 0%.

[26] Thus, the simulated δ_j draw confers a *comparative* advantage to a carline with respect to the location of part production—not an *absolute* cost advantage which would affect the initial market and employment shares.



(a) Cars   (b) Light trucks

Fig. 12. Laffer curves for parts and employment, fixed assembly.

Laffer curves. Focusing first on cars, we see that the new USMCA (RCR=75%) content requirement is set beyond the peak of both employment Laffer curves for all three assembly locations. Thus, we predict that a lower content requirement would have led to *both* higher employment and higher consumer surplus (we report the predictions for prices and consumer surplus later in this section). Compared to the old NAFTA content requirement (RCR=62.5%), the USMCA slightly raises employment for parts: 0.6 percentage points (pp) for Canada, 0.1 pp for Mexico, and 0.2 pp for the United States (see appendix Table G.1 for the complete set of results). This is much less than industry associations predicted. More importantly, the USMCA lowers combined employment across parts and assembly: −0.3 pp for Canada and the United States and −0.4 pp for Mexico. Had the US-proposed 85% rule gone into effect, the combined employment losses would have been more severe: −2.6 pp, −2 pp, −1.3 pp for Canada, Mexico, and the United States.

Qualitatively, the same results hold for trucks produced in the United States. The new USMCA is set beyond the peak of both employment Laffer curves. Compared to the NAFTA content requirement, the new USMCA raises part employment by 0.5 pp while reducing combined part and assembly employment by 0.1 pp. That employment loss would have been more severe, at 1.2 pp, at the US-proposed 85% RCR.

The results for trucks assembled in Canada and Mexico differ substantially due the much higher 25% MFN tariff levied for all non-compliant trucks exported to the United States (the main destination for those vehicles). In those cases, the stricter content requirements in the new USMCA induce combined employment increases (2.5 pp for Canada and 2.9 pp for Mexico). However, as we detail later, those cases are also associated with larger consumer surplus losses.

5.2. Endogenous assembly location: Extensive and intensive margin

In our last counterfactual, we allow for the RoO to lead to assembly relocation—following both theoretical extensions in Section 3. This captures the longer-run predictions for the impact of stricter content requirements on the extensive margin of vehicle assembly—along with the intensive margin of the vehicle production adjustment at a given assembly location. We use the same calibration parameters for the draws of the assembly share α_j and the Foreign cost advantage δ_j. In addition to the non-compliance tariff penalty for the current assembly location, we also construct a set of tariff penalties for alternate potential assembly locations: We allow for both intra-RTA relocation to one of the other two North American locations, and a Foreign assembly location outside North America.[27]

We detail the construction of the alternate tariff penalties in Appendix F. Our approach abstracts from differences in assembly costs across the potential locations, setting the parameters ω^R (for assembly relocation within North America) and ω^F (for assembly relocation outside North America) to one. This lets the assembly relocation decision be entirely determined by the core features of the model: differences in part costs and the non-compliance tariff penalties. And lastly, we set the part trade cost parameter to $\kappa = 1.2$. This parameter only affects the potential assembly relocation outside North America: In that case, the Foreign parts are 20% cheaper; and conversely the North American parts are 20% more expensive.[28] As we assumed in our theoretical model, we abstract from part trade costs within North America.

The resulting Laffer curves for the change in the average part share and employment are reported in Fig. 13. Looking first at the response of the average part share, we see that the option of assembly relocation substantially dampens the potential for the content requirements to induce increases in regional part sourcing. This dampening is particularly stark for the case of trucks assembled in Canada and Mexico that we had previously highlighted. When assembly relocation was not possible, the high 25% US MFN induced those truck producers to raise their regional part sourcing in response to the stricter content requirements in the new USMCA. Relative to the old NAFTA, the average part share rose 10.4 pp for Canadian trucks and 11.1 for Mexican trucks (see Appendix Table G.1). But when relocation is possible, many of those truck producers choose to relocate to the United States instead of complying with the higher content requirements. This significantly reduces the cost of non-compliance as all truck sales to the United States are no longer subjected to the 25% tariff. When relocation is possible, the new USMCA raises the average part share by 1.6 pp for Canadian trucks and 0.8 pp for Mexican trucks (see Appendix Table G.1).

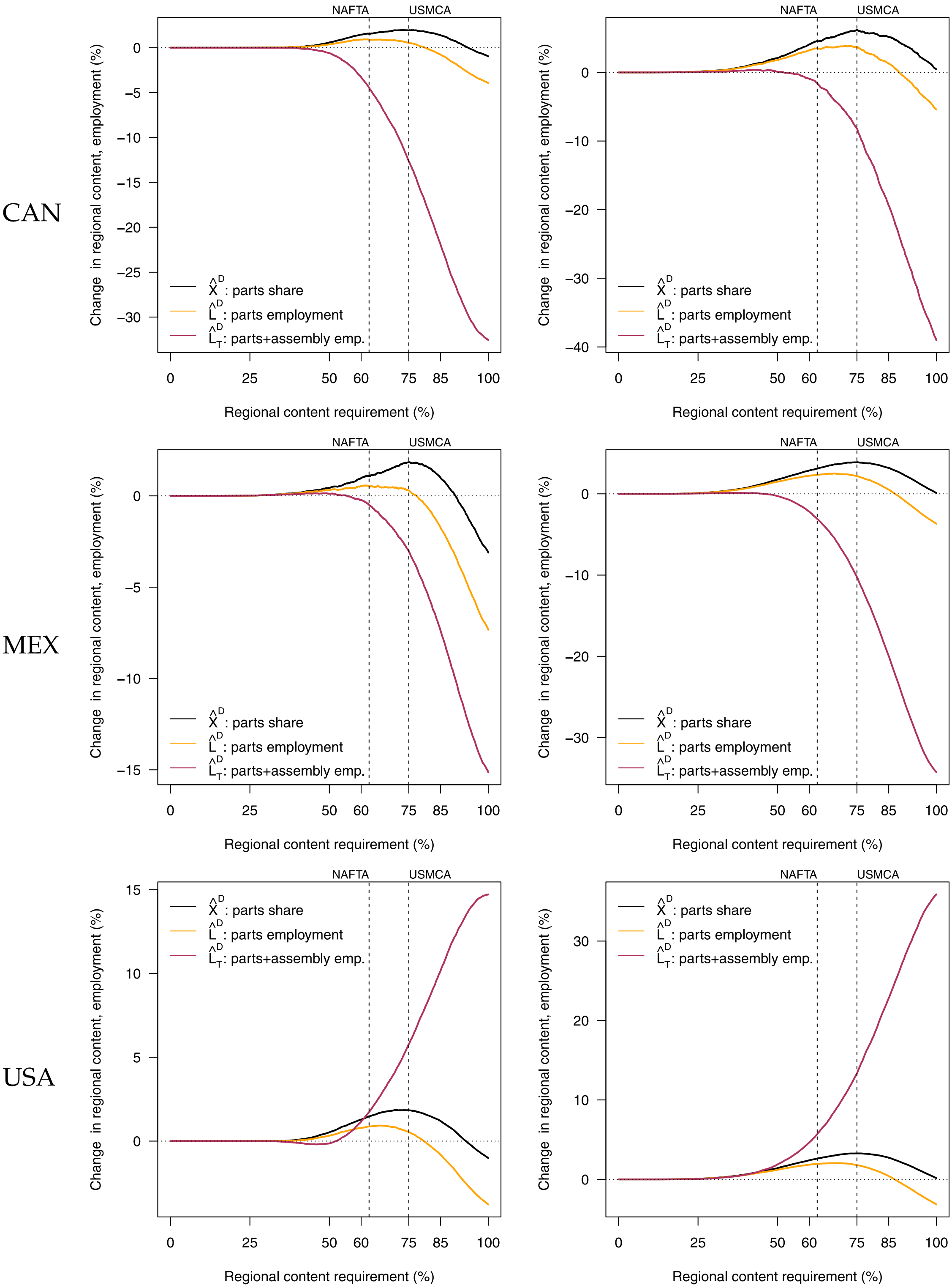
When we incorporate the impact of the RoO on higher vehicle prices and lower production, we find that the Laffer curves for part employment (the orange line in Fig. 13) peak at an RCR below 75% in *all* cases—including the cases of Canadian and Mexican trucks. In other words, a less strict content rule than the one adopted in the new USMCA would raise both part employment and consumer surplus for all cars and trucks assembled throughout North America.

Turning to the Laffer curve for combined part and assembly employment (in red), a very different picture emerges. The response of this combined employment is dominated by the response of the assembly employment to the intra-North American relocations induced by stricter content requirements. As we described for the case of Canadian and Mexican trucks, many vehicle producers can avoid the cost of complying with stricter content requirements by relocating assembly to the United States. In most cases, the tariff penalties are low because only a small proportion of those sales are exported to Canada and Mexico—and thus hit with the MFN tariff due to non-compliance. Therefore, we see a strong divergence between the combined employment Laffer curves for Canada and Mexico on one hand—and the United States on the other: stricter content requirement induce assembly relocation from Canada and Mexico to the United States, thereby lowering assembly employment in the former and raising it in the latter.

The Canadian and Mexican losses are similar for trucks, but Canada's employment reductions in cars are more severe than Mexico. The reason for these differences are that the simulation predicts that a large share of carlines in Canada move to the United

[27] A stricter RoO has no impact on assemblers outside NAFTA. Their costs of exporting to North America from abroad do not change and their costs of production would be increased by the RoO if they were to relocate assembly to North America.

[28] In Appendix G, we report the same set of counterfactual results for the case of a 10% and 30% trade cost. Qualitatively, they are similar to the 20% case.



(a) Cars (b) Light trucks

Fig. 13. Laffer curves with assembly relocation, $\kappa = 1.2$.

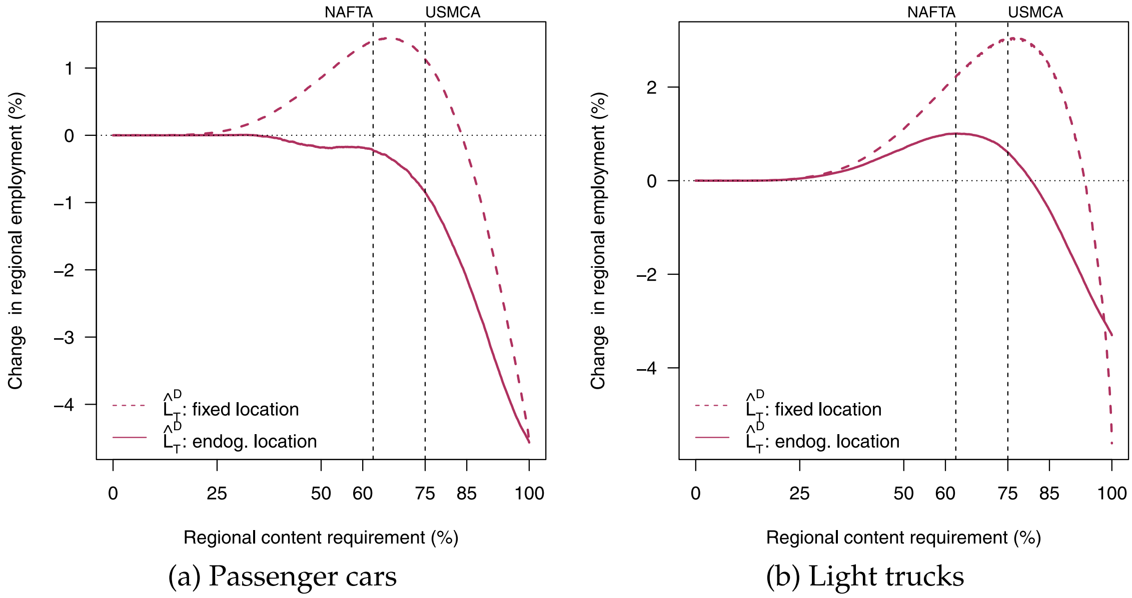


Fig. 14. North American Laffer curves for total employment.

States once the 75% RCR is fully implemented. A much higher share of Mexican-made carlines instead opt to stay in Mexico but cease to comply. This is because Mexican-made carlines have much higher τ^R because of a combination of a high MFN (35%) and higher sales shares within Mexico and to external markets. In contrast, Canada's car MFN is 6% and Canada has a lower share of sales for most carlines made in Canada and only a two percent sales share in non-NAFTA markets.

In the longer time frame allowing for relocation of assembly plants, employment losses are substantial in Canada (−8.1 pp for cars and −6.7 pp for trucks) and Mexico (−2.5 pp for cars and −7.1 pp for trucks). The US auto sector sees employment growth of 4.1 pp (cars) and 7.6 pp (trucks). Had the US achieved its negotiating goal of an 85% RCR, the employment gains would have been 8.5 pp (cars) and 17.1 pp (trucks).[29]

However, all these longer-run US employment gains from assembly relocation are zero-sum for the NAFTA region as a whole. At that regional level, those combined employment changes are driven by two forces: The impact of the RoO on the average regional part share (the black curves in Figs. 12 and 13) and its impact on higher vehicles prices. The former contributes to an increase in part employment so long as the RCR is not on the backward bending part of the Laffer curve; while the latter always contributes to both part and assembly employment losses. The resulting combined employment changes, $\hat{L}_T$, are shown as a function of the RCR in Fig. 14 – for both cars and trucks, and for both fixed (dashed line) and endogenous (solid line) assembly location.

When assembly location is fixed, the resulting regional employment Laffer curve averages the country-level counterparts for combined employment in Fig. 12. We thus obtain Laffer curves (dashed lines) with very similar shapes. For the case of cars, we described how the new USMCA at 75% induced combined employment losses for all three countries. Those losses are therefore reflected for the region as a whole, resulting in a .3 pp decrease in combined employment. For the case of trucks, we discussed how the new USMCA at 75% induced employment losses for the US and gains for Canada and Mexico (due to the much more severe non-compliance tariff penalty). On balance, the gains for the trucks assembled in Canada and Mexico dominate the losses for those assembled in the US, and there is a regional gain of .8 pp.[30]

In the longer run when the assembly location is endogenous, the shape of the Laffer curves for combined regional employment changes dramatically (solid line in Fig. 14). When assembly location is endogenous, the potential for a RoO to raise the average part share is significantly dampened (see our previous discussion for Fig. 13). This is the only force that can potentially raise employment. The second force induced by the higher vehicle prices always impacts employment negatively and is now a much more important contributor to the overall employment response. For the case of cars, that negative force completely unwinds any positive effect on employment from the increase in the average part share. The resulting Laffer curve for regional employment is then either flat or decreasing. For trucks, the positive effect from the increase in the average part share initially dominates for low RCRs; but this is reversed as the RCR increases beyond the old NAFTA level of 62.5%. For both cars, and trucks, the new USMCA at 75% (relative to the old NAFTA at 62.5%) induces combined regional employment losses: .6 pp for cars, and .4 pp for trucks. And because both of those regional employment Laffer curves decrease sharply with even more restrictive content requirements, the impact of the

29 Recall that without assembly relocation, Fig. 12 points to a decline in employment for cars when moving from NAFTA's 62.5% RCR to the proposed 85% RCR in all three countries.

30 See Appendix Table G.1 for numerical results at RCRs of 62.5% (old NAFTA), 75% (new USMCA), 85% (US proposal).

Table 2
Price and consumer surplus (CS) changes.

Assembly Country	RCR (%)	(1) Fixed loc. Price	(2) CS	(3) Endog. loc. Price	(4) CS
Passenger cars					
	62.5	0.29	−0.87	0.13	−0.38
CAN	75	0.73	−2.16	0.30	−0.91
	85	1.27	−3.71	0.49	−1.44
	62.5	0.19	−0.57	0.10	−0.29
MEX	75	0.45	−1.34	0.31	−0.91
	85	0.75	−2.22	0.58	−1.73
	62.5	0.16	−0.48	0.12	−0.35
USA	75	0.38	−1.13	0.29	−0.85
	85	0.63	−1.87	0.46	−1.35
Light trucks					
	62.5	0.37	−1.10	0.22	−0.67
CAN	75	1.11	−3.25	0.54	−1.61
	85	2.35	−6.73	0.89	−2.64
	62.5	0.34	−1.00	0.18	−0.53
MEX	75	1.02	−3.01	0.40	−1.19
	85	2.23	−6.39	0.63	−1.87
	62.5	0.18	−0.54	0.15	−0.45
USA	75	0.44	−1.31	0.34	−1.00
	85	0.76	−2.26	0.53	−1.59

Notes: The price changes are ($\hat{P}^D - 1$, shown in %) are relative to an RCR of 0. Changes in consumer surplus are given by $(\hat{P}^D)^{1-\eta} - 1$ (in %). They are defined for the set of carlines assembled in the country in the first column. The three RCR correspond to NAFTA (62.5%), USMCA (75%) and the US proposal (85%). Columns (3)–(4) assume $\kappa = 1.2$.

higher RCR at 85% proposed by the US negotiators would have engendered much more severe employment losses for the regional motor vehicle industry: 1.8 pp for cars and 1.6 pp for trucks.[31]

5.3. Consequences for vehicle prices and consumer surplus

In this section, we report the price increases – and associated consumer surplus decreases – associated with the RCRs at 62.5% (old NAFTA), 75% (new USMCA), and 85% (US proposal). Table 2 shows those percentage changes by country of assembly (P^D) and vehicle type relative to the case of no content requirements (RCR= 0). Columns (1) and (2) show the fixed assembly case, and columns (3) and (4) show the case with endogenous assembly. The even-numbered columns show the change in consumer surplus associated with those price changes, $(\hat{P}^D)^{1-\eta}$.[32]

The move to the USMCA RCR (75%) raises the overall price index for cars from a given assembly location in the range of 0.22 pp (0.38–0.16) to 0.44 pp (0.73–0.29). Prices increase more for light trucks, with a maximum of 0.74 pp. For both cars and trucks, prices increase by the greatest amount in Canada and the lowest amount in the United States. This dampening of cost increases is even stronger when carlines are given the extra option of relocating assembly in response to higher RCRs. In the case with the largest cost increases – Canada for trucks – the 0.32 pp (0.54−0.22) price increase with relocation is less than half its counterpart without relocation.

6. Conclusion

We analyzed how heterogeneous firms respond to rules of origin when they face the choice of within-RTA or outside-RTA part sourcing for a large number of parts. Firms can choose to comply with the RoO, which raises their part cost when their unrestricted sourcing choices would not comply with the RoO. Or firms can choose not to comply and pay the tariff penalty on their intra-RTA exports. When the RoO is below a threshold, the former compliance effect dominates and the average regional part sourcing increases with the RoO—at the expense of higher costs, and hence higher prices for consumers. But when the RoO rises above a threshold, the latter non-compliance effect dominates and a tighter RoO then leads to both *lower* regional part sourcing and higher costs and consumer prices. We call this the RoO Laffer curve.

We use comprehensive data on the part cost shares and sales by destination for all car and light truck models assembled in North America to fit the parameters of our theoretical model, augmented with some additional parameters to capture the variations that

[31] As we describe in more detail in the following section, the price increases from the strictest content requirements at 85% are magnified when assembly is fixed. That price response is even further magnified as the RCRs becomes even stricter. This is why the employment Laffer curve for fixed assembly dips below the endogenous assembly curve at the highest RCRs (near 100%) for trucks.

[32] See Appendix E for the associated derivations.

we observe in the data. This allows us to construct counterfactual predictions for any given RoO. We do not analyze the policy planner's optimal choice of a RoO, which would depend on the weights placed on producer surplus and employment in both the part and final good sectors, as well as consumer surplus for the final good.

However, when the RoO is on the backward bending portion of the Laffer curve, then relaxing the rule would lead to both higher production (and associated employment) and higher consumer surplus (from lower prices). Hence, there are no positive weights for employment and consumer surplus that would lead to an optimal RoO on that backward bending portion of the Laffer curve. Instead, we report the full simulated RoO Laffer curves, along with the associated impacts for prices and consumer surplus at the key levels of the RoO that were considered and implemented for motor vehicles in the NAFTA and USMCA agreements: The 62.5% content requirement in the old NAFTA, the new stricter 75% level negotiated in the new USMCA, and the 85% level proposed by the USTR.

The higher costs brought about by stricter RoOs will raise prices for vehicles assembled in North America, favoring imports into North America from countries that are not affected by the RoO. We add more structure for competition, demand, and employment, and construct additional Laffer curves for part employment and combined part and assembly employment that incorporate the negative impact of stricter content requirements on vehicle production. Once we incorporate this channel, we find that the stricter USMCA content requirements – relative to NAFTA – *negatively* affect combined employment, except for the case of trucks assembled in Canada and Mexico. For those trucks, the high 25% U.S. MFN tariffs induce many more producers to comply with the stricter USMCA content requirements and increase their regional part sourcing, at the expense of higher costs that are passed on to truck consumers. Setting aside those two cases, the new USMCA content requirements thus lead to decreases in *both* overall employment (production levels) and consumer surplus. Those joint predicted negative consequences are possible because the new USMCA content requirements are on the "wrong" side of the combined employment Laffer curve. The U.S. proposed 85% rule is even further along that backward bending portion of the Laffer curve. Had that rule been adopted, the negative consequences for employment and consumer prices would have been significantly amplified.

These are medium-run implications that hold the location of assembly fixed. In the longer run with endogenous assembly, the potential for content requirements to raise regional part sourcing is significantly muted: as the RoO becomes stricter, producers relocate assembly rather than comply with the stricter rules. For both cars and trucks and the three North American assembly locations, the stricter content requirements in the new USMCA are ineffective in raising regional part production and the associated employment making parts: The small increases in part sourcing are wiped out by reductions in vehicle production due to higher prices. In the long run, the model predicts that the USMCA RoO will redistribute auto employment from Canada and Mexico to the United States, with a small net decrease for the region as a whole.

It is too early to evaluate these quantitative predictions for the North American motor vehicle industry. The new USMCA entered into force in the summer of 2020, when car production was recovering from the Covid shutdowns. The following years also featured confounding effects of supply chain disruptions and government stimulus programs. Another practical difficulty of evaluating the change in RoOs is that many firms agreed to "alternative staging regimes" that allow them to postpone compliance decisions. Future work will evaluate whether the stricter content requirements in the new USMCA were successful in raising North American part sourcing and the associated consequences for vehicles prices; and the extent to which the new USMCA induces assembly relocation away from Canada and Mexico towards the United States.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

https://data.mendeley.com/datasets/fdhyg8kz8m/1.

Appendix A

An online appendix for this article can be found online at https://doi.org/10.1016/j.jinteco.2024.103911.

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