Rules of Origin and Auto-Parts Trade

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Abstract

Recent decades have witnessed the growing importance of trade in intermediate goods and pursuit of free trade agreements (FTAs). They distort firms' sourcing decisions internationally through preferential tariffs and rules of origin (RoOs), a set of criteria that define the origin of a product to qualify for preferential access. The paper distinguishes trade diversion through RoOs from tariff reduction on intermediate goods, focusing on the automotive industry. Car assemblers' decisions of how much to acquire from which supplier are modeled for every auto part. With the derived gravity trade equation, the estimation identifies significant diversion in intermediate sourcing and the effect is nonlinear with respect to the restrictiveness of RoOs. The shift from foreign to regional inputs increases before a sharp decline when the required minimum FTA content reaches 65%. Impacts of RoOs are further decomposed to three channels: export destinations of final goods, magnitude of preferential treatments and value of intermediate goods. Results show that the RoO effects are stronger when car exports are mainly intra-FTA, but indifferent to preferential margins of cars or values of parts.

Keywords: Rules of Origin, intermediate inputs sourcing, RTA, automotive.

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1 Introduction

Since 2016, a set of free trade agreements have drawn unprecedented attention led by the formation, renegotiation, or separation of some world's largest free-trade areas, namely the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), the United States-Mexico-Canada Agreement (USMCA), the Regional Comprehensive Economic Partnership (RCEP), and the EU-UK Trade and Cooperation Agreement (TCA). One central detail that governments have been wrestling with is how to determine whether a product is eligible for preferential treatment in an agreement, especially when it comes to sensitive sectors, such as the auto industry. CPTPP adopted a generous rule of regional value content (RVC) on duty-free vehicles at 45%, which means that automobiles need to be manufactured using at least 45% of content created intra-FTA. There has been vigorous opposition in some member countries, such as Canada, arguing that the liberal rule contradicts what is demanded by the US in USMCA, an increasingly stricter standard from 62.5% to 75%. In Asia, RCEP consolidates various rules in the existing five "ASEAN+1" agreements. Firms no longer need to reformulate the production to comply with different rules, and instead they manufacture products to qualify a single set of RCEP criteria, which is fairly low at 40%. As for the EU-UK trade deal, there has been back and forth negotiations on the content rule of electric vehicles.

Debate over these trade agreements sheds light on a commercial policy instrument which used to be less transparent: rules of origin (RoOs). It functions as a set of criteria to determine the origin of products and whether products can be granted preferential tariff treatment. Complementary to the preferential terms among FTA members, RoOs are designed to curb exports from third countries to transship goods to the FTA through the member with the lowest external tariff (trade deflection).[1] As such, researchers historically regard RoOs as a "supportive" role for regional integration. Nevertheless, with the dramatic growth of intermediate goods trade which accounts for almost two thirds of international trade (Johnson and Noguera, 2012), the production chain of final goods evolves to be an increasingly sophisticated network across industries and geographical locations. A commonly cited case is Apple iPod in Dedrick et al. (2010), whose production involves memory chips from South Korea, battery from Japan, controller chip from the US and assembly in China. The answer to where a final product originates is thus no longer straightforward. In this context, rules of origin reshape firms' input allocation by defining a product's "nationality".

Rules of origin distort sourcing decisions beyond the traditional trade diversion effects of preferential tariffs.[2] If RoOs are not too liberal to leave firms unconstrained, a final good producer

[1] In this paper, I define that trade diversion occurs when an importer chooses a less efficient source because of regional preferences, whereas trade deflection occurs when tariffs on one destination cause the exporter to send her goods to a different destination.

[2] See Caliendo and Parro (2015), Amiti and Konings (2007), and Bas and Strauss-Kahn (2015) for studying effects

faces a dichotomy. On one hand, she can enjoy the low tariff when exporting final goods to the trade bloc in exchange for procuring a required share of inputs within the region which could be less cost-effective sources. On the other hand, she can source from the cheapest input suppliers anywhere but lose the origin status and pay MFN tariffs when crossing partners' borders. Given export decisions, firms choose whether to comply with the rules or not. For compliers, RoOs divert trade of intermediate inputs to the free trade region even without tariff reduction for inputs. For non-compliers, there could be other margins of firm adjustment, such as reorganizing export or relocating production. A restrictive RoO could backfire when more firms defy the rules or even shift the production to countries with laxer requirements.

I develop a theoretical model to analyze firm's decisions on where and how much to source each input facing the rules of origin constraint in a multi-country and multi-product world. The key focus of this model is to incorporate RoO as implicit costs of importing intermediates from countries outside the free trade region. Built upon Antràs and Chor (2013) and Antras et al. (2017), the model allows marginal products of different inputs in producing the final good to vary but is silent on the extensive margin decisions on offshoring which is the focus in Antras et al. (2017). Having different marginal product of inputs helps to build a micro foundation featuring heterogeneity in intermediate imports along the product dimension. The model yields a gravity trade equation for every intermediate goods, and guides the estimation to be tractable.

Legal complexity and inconformity of rules of origin presents a major empirical challenge in studying their effects.[3] The practice with regard to RoOs varies across regional trade agreements and industries, with some defined in terms of change in tariff headings, others the regional value content (RVC) criterion and yet others requirements of manufacturing or processing operation. For this reason, the existing empirical papers on RoOs have focused on a single trade agreement (Anson et al. 2005, Conconi et al. 2018 and Head et al. 2021 on NAFTA, Sytsma 2019 on EU Generalized System of Preferences). To accommodate the lack of uniformity in rules across sectors, they either use a synthetic index approach as in Estevadeordal (2000) or count the number of linked final goods that are subject to RoOs like Conconi et al. (2018), or else exploit an event study.[4] This paper differs in focusing on a single industry, the automotive, where global sourcing is prevalent and, most importantly, regional value content criterion is consistently applied by different RTAs. It allows me to rank RTAs according to the regulated share of value originating from member states

of tariff liberalization.

[3]Rules of origin are very detailed in regional trade agreements. For example, NAFTA's annex on rules of origins is close to 200 pages.

[4]The index constructed by Estevadeordal (2000) and also used in Anson et al. (2005) measures the restrictiveness of preferential rules of origin from 1 being the least restrictive to 7 being the most restrictive. It is based on the type of rules implemented, technical rule being the most restrictive practice, followed by value content and lastly change in tariff classifications. Conconi et al. (2018) consider the input-output linkage in counting the number of sourcing restrictions that affect intermediate goods in each sector.

out of the value of a car as a measure of RoO restrictiveness. Using observed RVC thresholds avoids measurement error in self-constructed indices, and is consistent with the way my framework and other theoretical papers have modeled RoOs.

Leveraging the derived gravity equation on trade in intermediates and variation in local content requirements across RTAs, I first unpack the effects of regional trade agreements on intermediate goods trade to two distinct channels: preferential intermediate tariffs and rules of origin on downstream outputs. I examine RoO annexes on the automotive industry for 23 RTAs from 2000 to 2014, which cover 40 major economies and 26 HS6-digit auto parts. Results show that RoOs indeed facilitate trade diversion. The impact of RTAs on intermediates trade would be equivalent to the removal of 19% *ad-valorem* tariff when the associated content rule is below 60% and equivalent to 53% tariff removal when RVC is above 60%. Furthermore, the degree of trade diverted is hump shaped with respect to the restrictiveness of RoOs. As the content rule goes beyond 65%, the average shift of foreign sourced inputs to regionally sourced ones is about the same magnitude to RTAs with less than 50% RVCs, suggesting more firms defy the rules and relocate their production elsewhere.

Beyond the trade diversion effects of RoOs, the paper further explores firms' heterogeneous responses to RoO changes. Specifically, I test whether export destinations of cars, the magnitude of preferential benefits, and different car parts would vary the results. When the majority of foreign consumers are intra-RTA or the preferential margin on car exports is high, car exporters' benefits from complying RoOs are likely to outweigh costs. At country level, increase in the number of compliers leads to larger diversion in intermediates sourcing. Moreover, RVC thresholds may work differently across parts depending on what gets to be redistributed first. I find where cars are sold matters to the sourcing of car parts, but the effect of exported cars' preferential margin is weak. There is neither systematic difference in RoO effects across parts.

This paper adds to a growing body of literature on rules of origin. Much interest on earlier works has been on theory (Krishna and Krueger, 1995; Krueger, 1997; Falvey and Reed, 2002; Krishna, 2005; Ju and Krishna, 2005). Recently, empirical studies start to rise. The most closely related paper is Conconi et al. (2018) in which they use difference-in-difference to show RoOs reduce the growth rate of imports of intermediate goods from third countries to Mexico relative to NAFTA partners by around 45%. Anson et al. (2005) also document negative impact of RoOs on imports and that the compliance costs of NAFTA RoOs on Mexican exporters amount to 47% of the preferential margin. Sytsma (2019) finds the RoO in EU to Bangladesh textile exporters cuts three-fourths of the preferential margin. Several other papers provide evidences that liberalising rules of origin increases export (Andersson, 2016; Tanaka, 2021; De Melo and Portugal-Perez, 2014). The most recent study by Head et al. (2021) focuses on the auto industry as well. They establish a RoO Laffer curve where production of car parts within USMCA first expands and then contracts with increasing content requirement, taking into account adjustment on firm types (compliant-unconstrained, compliant-constrained, and non-compliant) and relocation of assemblers. Their theory is corroborated by some of the empirical results in this paper.

The paper continues as follows. I first adapt the existing model to include rules of origin as a form of trade frictions. Derived from the model, trade elasticities can be estimated separating the effects of RoOs from others in a RTA. Refinements are then performed to test for any heterogeneous effects related to export decisions and intermediate goods characteristics.

2 A Model of Global Sourcing under Rules of Origin

I develop a multi-country and multi-product sourcing model that characterizes how much and where final good producers import every intermediate inputs. Geography is categorized by countries where intermediate suppliers locate, final good producers locate, and markets where final goods are sold. To study rules of origin, I restrict the second and third type of locations to the same set which is bonded by a free trade agreement, whereas locations of intermediates can be global. Compliers of RoOs are constraint in sourcing from countries outside of the FTA region as if a hypothetical tariff on intermediates is imposed between FTA members and other countries.

2.1 Consumer preferences and demand

Consider a free trade bloc $\mathcal{N}$ consisting of countries where individuals have common preferences. For model tractability, I let trade in cars entails zero costs among FTA member countries and assume away any frictions including distances, and thus, there is no price arbitrage. It allows me to model aggregated demand for the entire bloc instead of each country. A representative consumer in $\mathcal{N}$ values the consumption of different varieties of cars from a set Ω according to a standard constant elasticity of substitution (CES) aggregator

$$U = \left(\int_{\omega \in \Omega} (\varphi_\omega \tilde{q}_\omega)^\rho d\omega \right)^{1/\rho}, \ \rho \in (0,1), \tag{1}$$

where φ_ω represents the quality of variety ω perceived by all consumers in the bloc and $\tilde{q}_\omega$ is its consumption in physical units. Denote E as the total expenditure on the automotive industry summing across the member countries. Maximizing utility subject to the budget constraint $\int_{\omega \in \Omega} p_\omega \tilde{q}_\omega d\omega = E$ gives rise to the following demand featuring a constant price elasticity for variety ω:

$$q_\omega = A_\omega p_\omega^{-\frac{1}{1-\rho}}, \tag{2}$$

where $q_\omega \equiv \varphi_\omega \tilde{q}_\omega$ is the quality-adjusted output. The variety-specific demand shifter, $A_\omega = E\left(P^\rho \varphi_\omega\right)^{1/(1-\rho)}$, depends on the industry-wide demand for the set of countries and consumers' taste towards the variety of car. I assume firms treat A_ω as exogenous. P is the standard price index accounting for the taste differences across varieties available to these markets.

2.2 Firm's problem conditional on sourcing location

Each differentiated variety is produced by a single car manufacturer who locates at $\ell \in \mathcal{N}$ within the bloc. Firms are then also indexed by ω. They are heterogeneously defined by their core productivity δ_ω. Production of final car varieties requires assembly of a continuum bundle of intermediates, denoted by j on an unit interval. Firms decide how much and where to procure parts given the demand of its variety within the trade bloc characterized by equation (2). Sourcing of parts, however, is not restricted to the member countries only, but a broader set $\mathcal{I}$. I leave firms' export decisions to markets outside of the trade bloc and the joint determination of both exports and imports for future extensions. Instead, I focus on the group of firms who are always constrained by rules of origin and choose to comply, named "compliant-constrained" in Head et al. (2021).

Intermediates are produced by competitive parts suppliers from a country set $\mathcal{I}$ where each supplier is denoted by ji where $i \in \mathcal{I}$. A part supplier engages either in a relationship-specific production or in an outside option with value zero. Since every part is fully customized to a variety of car, neither can parts suppliers resell to alternative buyers. In a case where contracts between car assemblers and parts suppliers are perfectly enforceable and complete, assemblers make an offer to pay p_j in exchange for x_j amount of compatible inputs j for each part. Suppose the optimal sourcing strategy is $\{i^*(j), \forall j \in [0,1]\}$, the quality-adjusted volume of a car variety ω follows a CES production function,

$$q_\omega = \delta_\omega \left(\int_0^1 (\psi_j x_{j(i^*)\omega})^\alpha dj \right)^{1/\alpha}, \tag{3}$$

where ψ_j captures the marginal product of different car parts which is non-negative and continuously differentiable.[5] Intermediate inputs are combined with a symmetric elasticity of substitution equal to $1/(1-\alpha)$ where $\alpha \in (0,1)$. They are imperfectly substitutable along the quality dimension, but not the engineering process. For example, an assembler may compensate inferior wheels with leather seats cover to meet the same level of quality perceived by consumers.

With complete control over the investments and prices of all components, a car manufacturer maximizes his profits by offering the optimal contract such that only the lowest cost parts suppliers

[5] Another way is to ignore substitutability and model a Leontieff production function which is a special case of the CES specification.

$\{i^*(j), \forall j \in [0,1]\}$ would participate. Mathematically,

$$\max_{\{x_{j\omega}, p_{j\omega}\}_{j\in[0,1]}} \pi_\omega = A_\omega^{1-\rho}\delta_\omega^\rho \left(\int_0^1 (\psi_j x_{j\omega})^\alpha dj\right)^{\rho/\alpha} - \int_0^1 p_{j\omega}x_{j\omega}dj \\ \text{s.t. } p_{j\omega}x_{j\omega} - c_{j(i^*)\omega}x_{j\omega} \geq 0. \tag{4}$$

Part j supplier in country i^* incurs unit cost $c_{j(i^*)\omega}$. I show in Appendix that solving this problem delivers the optimal amount of input j, pricing, and associated firm profits to be

$$\begin{aligned} x_{j\omega}^* &= \frac{A_\omega}{\psi_j}\left(\rho\delta_\omega^\rho\right)^{\frac{1}{1-\rho}}\left(v_{j\omega}^*\right)^{\frac{1}{1-\alpha}} V_\omega^{\frac{\rho-\alpha}{(1-\alpha)(1-\rho)}} \\ p_{j\omega}^* &= c_{j(i^*)\omega} \\ \pi_\omega^* &= (1-\rho)A_\omega\left(\rho\delta_\omega V_\omega\right)^{\frac{\rho}{1-\rho}}, \end{aligned} \tag{5}$$

where $v_{j\omega}^* = \psi_j / c_{j(i^*)\omega}$ indicates the marginal product per unit of cost and $V_\omega = \left[\int_0^1 \left(v_{j\omega}^*\right)^{\frac{\alpha}{1-\alpha}} dj\right]^{\frac{1-\alpha}{\alpha}}$ is an aggregator of cost-adjusted quality of all intermediates. The discussion of whether the quality-adjusted investment on inputs are complements or substitutes depending on the relative size of α and ρ follows similar rationale in Antràs and Chor (2013) and Alfaro et al. (2019). When ρ is smaller than α and demand of a final car is more elastic, any additional investment on quality improvement of a particular part can significantly reduce that of other parts, making them substitutes in quality terms. The suppliers' participation constraint is binding for the lowest cost parts producers, which leaves them with the same payoff as the outside option at zero. Car assemblers extract all the rents.

Now let's characterize the marginal cost of part j supplier from country i shipping to assembler ω at ℓ,

$$c_{ji\omega\ell} = \frac{w_i}{z_{ji\omega}}\tau_{ji\ell}r_{i\ell}d_{i\ell}, \tag{6}$$

where w_i is a composite index of wages and material prices for car parts production in sourcing country i. Delivery of car parts is subject to a set of trade frictions from i to ℓ, namely *ad-valorem* tariffs on parts $\tau_{ji\ell} = 1 + t_{ji\ell}$, non-price factors such as distance that shifts transportation cost $d_{i\ell}$, and implicit costs on parts due to rules of origin placed on final cars $r_{i\ell}$. For RoO compliers who find the rules to be binding, $r_{i\ell} > 1$ if the part is sourced outside the region, i.e. $i \notin \mathcal{N}$, and $r_{i\ell} = 1$ otherwise. There could be other groups of firms who never find RoOs binding and those who choose not to abide the rule, in either case $r_{i\ell} = 1$ regardless whether county i belongs to the region $\mathcal{N}$ or not. Modeling the endogeneity of $r_{i\ell}$ which depends on firm-level decisions and identifying marginal switchers would further complicate the model and require more disaggregated data in estimation.[6] With limited data, I keep the model parsimonious but bear in mind that firms' heterogeneous responses to RoOs are embedded in $r_{i\ell}$ which will be investigated empirically in Section 4.

Another caveat is that firms may progressively source parts within the FTA region until the minimum requirement is met. The effective RoO constraint on different parts would then vary depending on their relative contributed value and cost advantages, although technically, the same content threshold is stated without specification to different parts. Solving which part is reallocated to domestic sourcing and which part remains foreign is a complicated combinatorial problem. Nevertheless, I extend $r_{i\ell}$ to $r_{ji\ell}$ in the empirical section and investigate whether effects are heterogeneous across parts.

Productivities of the compatible inputs, $z_{ji\omega}$, are supplier-assembler specific. I treat productivities of part j from country i for a car assembler ω as independent draws from the Fréchet distribution with CDF, $\exp(-z^{-\theta})$. Hence, the marginal product per unit cost of a part, $v_{ji\omega} = \psi_j / c_{ji\omega\ell}$, is distributed as

$$\Pr\left(v_{ji\omega} \leq v\right) = \exp(-\phi_{ji\ell} v^{-\theta}), \tag{7}$$

where $\phi_{ji\ell} = \psi_j^{\theta}\left(w_i \tau_{ji\ell} r_{i\ell} d_{i\ell}\right)^{-\theta}$ indicates country i's potential in supplying part j to country ℓ. The shape parameter θ governs the force of comparative advantage across suppliers from different countries for a specific part. The lower the θ, the higher the variability of productivities. Note that different car manufacturers who assemble their respective varieties at the same location would expect identically distributed parts suppliers.

2.3 Sourcing decisions

Observing equation (5), car manufactures choose the optimal part supplier who offers the lowest price of the part or equivalently the highest value per unit cost from the set of countries $\mathcal{I}$.[7] With equation (7) and properties of the Fréchet distribution, the distribution of value per unit cost for parts that are actually procured by car assemblers at ℓ is

$$\Pr(v_{j\omega}^{*} \leq v) = 1 - \exp(-\Phi_{j\ell} v^{-\theta}), \tag{8}$$

[6] The recent study by Head et al. (2021) makes theoretical contribution in modeling these margins.

[7] Implicitly, I assume all countries from the set $\mathcal{I}$ are capable of producing compatible inputs for every variety of car. Relaxation of this assumption will not affect the model structure. A gravity-type trade equation which is essential for the empirical estimation still holds.

where $\Phi_{j\ell} = \sum_{k\in\mathcal{I}} \phi_{jk\ell}$ is the sourcing capability of a country ℓ for a part j. The probability that i^* is selected for part j used in cars assembled at ℓ equals to

$$\Pr(\arg\max_{i\in\mathcal{I}} v_{ji\omega} = i^*) = \frac{\phi_{ji^*\ell}}{\Phi_{j\ell}}. \tag{9}$$

An alternative interpretation is that equation (9) is the share of assemblers in ℓ that source from part supplier ji^*. More assemblers choose parts suppliers from i^* if they have low costs to serve ℓ relative to others. Specifically, when RoOs are effective, sourcing within the FTA region has competitive advantage against sourcing outside, holding other cost factors equal. Following Eaton and Kortum (2002), another implication about the Fréchet distributed productivities is that the distribution of value per unit cost for part j that country ℓ sources from a particular country is independent of the sourcing country's identity and equals to the distribution in (8). Consequently, the share of assemblers in ℓ that source from ji^* is also the corresponding expenditure share.

2.4 Aggregation and gravity

From the optimal sourcing decisions of inputs in equation (5), the shipping flow of part j from the lowest-cost supplier to a car assembler ω in value term is

$$X_{j\omega} = \rho^{\frac{1}{1-\rho}} EP^{\frac{\rho}{1-\rho}} (\varphi_\omega \delta_\omega^\rho)^{\frac{1}{1-\rho}} \left(v_{j\omega}^*\right)^{\frac{\alpha}{1-\alpha}} V_\omega^{\frac{\rho-\alpha}{(1-\alpha)(1-\rho)}}. \tag{10}$$

To get the expected trade flow of part j from a country i^* to country ℓ, I need to aggregate the above taking into account the measure of heterogeneous firms in ℓ, their associated cost distributions when i^* is the source country, and the probability of choosing country i^*. Now, let's tackle each of the components.

I assume free entry for car manufacturers with entry cost F_ℓ for every $\ell \in \mathcal{N}$. Equation (10) reveals that the preference-based φ_ω and cost-based δ_ω are isomorphic in trade. Therefore, instead of separately specifying each variable, I assume the composite $\varphi_\omega \delta_\omega^\rho$ is drawn from a Pareto distribution with shape parameter η where $\eta > 1/(1-\rho)$. Free entry condition and variable profit in equation (5) give rise to the entrant's lowest productivity and quality cutoff being

$$\left(\underline{\varphi_\omega \delta_\omega^\rho}\right)^{\frac{1}{1-\rho}} = \frac{F_\ell}{(1-\rho)\rho^{\frac{\rho}{1-\rho}} EP^{\frac{\rho}{1-\rho}} V_\omega^{\frac{\rho}{1-\rho}}}. \tag{11}$$

Firms which above the threshold enter and actively source inputs from all potential suppliers since there is no fixed costs of importing.

Aggregating the variety-specific part usage in (10) to country ℓ where assembly of a set Ω_ℓ

varieties is processed, I obtain

$$X_{j\ell} = \kappa F_\ell \Omega_\ell \left(\frac{\Phi_{j\ell}}{\Phi_\ell} \right)^{\frac{\alpha}{(1-\alpha)\theta}}, \tag{12}$$

where constant is $\kappa = \frac{\eta\rho}{\eta(1-\rho)-1}$, and $\Phi_\ell = \left(\int_0^1 \Phi_{j\ell}^{\frac{\alpha}{(1-\alpha)\theta}} dj \right)^{\frac{(1-\alpha)\theta}{\alpha}}$ is a sourcing capability index of country ℓ across all the parts. The equation implies that if a part is higher value-added to the final car and also enjoys cost advantage among all the potential suppliers, it will be used more in producing the quality-adjusted final output relative to other parts. The relative difference is governed by the degree of substitution across parts and productivity dispersion across suppliers. The derivation is presented in the Appendix, which takes advantage of the setting where the cost distribution of parts that are actually sourced by a country is the same regardless of the identity of firms (varieties).

Combined with the sourcing probability in equation (9), export from country i^* to ℓ for part j is

$$X_{ji^*\ell} = \kappa \underbrace{F_\ell \Omega_\ell \Phi_\ell^{-\frac{\alpha}{(1-\alpha)\theta}} \Phi_{j\ell}^{\frac{\alpha}{(1-\alpha)\theta}-1}}_{\text{dest., part-dest}} \underbrace{\psi_j^\theta w_{i^*}^{-\theta}}_{\text{part, orig.}} \underbrace{(r_{i^*\ell} d_{i^*\ell})^{-\theta}}_{\text{orig-dest}} \underbrace{\tau_{ji^*\ell}^{-\theta}}_{\text{part-orig-dest}} . \tag{13}$$

The model yields a gravity trade equation at product level aggregating from firms' decisions. Trade in intermediate inputs is rising in marginal product of a car part and measure of assemblers, and decreasing in cost of parts production and trade frictions between the country pair for the input. Due to the substitutability across intermediate inputs introduced in the model, country ℓ's sourcing capability of other parts also affects trade negatively. Depending on the relative size of α versus θ, the effect of sourcing capability of country ℓ for the part j is ambiguous. If intermediate inputs are less substitutable (small α) and input producers from different countries are less dispersed (high θ), then increase in $\Phi_{j\ell}$ due to improvement in supply by any other origins will reduce sourcing of the part from i^* because business stolen by parts suppliers from other origins dominates expansion of the market for part j. The trade elasticity remains $-\theta$ as in Antras et al. (2017) when the extensive margin in sourcing is suppressed and all firms are capable of sourcing inputs from all countries.

Although this paper does not intend to structurally recover all the model primitives for counterfactual analysis, the gravity equation provides powerful guidance for understanding trade flows of intermediate inputs and estimating trade elasticities. Once observed variables measuring each type of friction are introduced, namely tariffs, rules of origin restrictiveness and non-price factors, I can apply the empirical counterpart of equation (13) to estimate each of their effects on trade.

As an extension of the benchmark model, I have mentioned in Section 2.2 that the effective RoO friction when sourcing outside of the trade bloc could vary by parts if there is systematic differences in which part to be shifted inwards first and which part to always be left out, which makes it $r_{ji\ell}$. The extension will not change the rest of the deviation, and the gravity equation becomes

$$X_{ji^*\ell} = \kappa \underbrace{F_\ell \Omega_\ell \Phi_\ell^{-\frac{\alpha}{(1-\alpha)\theta}} \Phi_{j\ell}^{\frac{\alpha}{(1-\alpha)\theta}-1}}_{\text{dest., part-dest}} \underbrace{\psi_j^\theta w_{i^*}^{-\theta}}_{\text{part, orig.}} \underbrace{d_{i^*\ell}^{-\theta}}_{\text{orig-dest}} \underbrace{(r_{ji^*\ell}\tau_{ji^*\ell})^{-\theta}}_{\text{part-orig-dest}}. \tag{14}$$

I will provide more details in Section 3.3 about constructing the proxy for $r_{ji\ell}$, and compare empirical results in equation (14) to (13).

3 Data and Variables

3.1 RTAs and RoOs

Rules of origin are critical components in regional trade agreements. In this paper, I study a period from 2000 to 2014 covering 23 RTAs and 40 major car and parts production countries including the U.S., Canada, Mexico, Brazil, China, Japan, South Korea, Thailand, India, 28 EU countries, Iceland, Norway, and Turkey. These RTAs are either still active in 2014 or once have been active during the studied time period. Information on each specific RTA such as years of entry into force and deactivation, parties involved, relevant articles and annexes about RoO provisions is provided by WTO Regional Trade Agreement Database and member countries' government websites.

The restrictiveness of rules of origin in this paper is measured through the minimum of regional value content required in order to be treated with preferential terms. Concentrating on a single industry, the automotive, allows me to exploit the observed thresholds rather than relying on relatively subjective indices. One may raise concern on whether RVC is sufficient to represent the stringency of rules of origin. RVC rules are normally used in combination with change of tariff classifications which requires any non-originating input must be sourced outside the same category with the final good at certain level. For example, consider a passenger car falling under HS sub-heading 8703.21-8703.90. NAFTA rules of origin require the following:

"A change to subheading 8703.21 through 8703.90 from any other heading, provided there is a regional value content of not less than 62.5 percent under the net cost method."

The first part means that non-originating input in a passenger car requires a HS heading change, i.e. not coming from heading 8703 ("motor cars & vehicles for transporting persons"). The second part imposes additional constraint which the cost of inputs sourced within NAFTA has to be at least 62.5% of the total net cost for a final car. Considering car parts that are mostly under the heading of 8708 ("parts & access for motor vehicles") and 8407 ("spark-ignition reciprocating or rotary internal combustion piston engines") but none under the same heading with passenger cars, the change of classification restriction is clearly not binding. What matters for the sourcing of car parts is mainly the RVC threshold.[8] In general, the fact that change of classification rule is unbinding in the automotive industry applies to other RTAs as well. Therefore, RVC is a valid instrument for RoO stringency, at least for cars.

How regional value content is calculated goes further in details. Generally two methods are used, transaction value or net cost. The first is based on value of non-originating materials in which RVC is equal to one minus the share of non-originating materials' value in adjusted price of the good.[9] The net cost based approach replaces transaction price to net cost of the good and calculates RVC using the share after subtracting value of non-originating materials over total net cost of the good. Most RTAs in my sample use the net cost method for cars. However, some also provide transaction value method as an alternative and either can be used with slightly different threshold, in which case I choose the more stringent content rule.

A list of regional trade agreements in my sample and their respective value content rules on the automotive industry is presented in Table 1. RVC ranges from 35% to 65%, but at the level of country pairs, most are concentrated at 60% as a harmonising initiative by the EU except for the agreement with South Korea. The lack of variation becomes problematic when I include both a RTA dummy and RVC in a regression due to high collinearity, which I have carefully dealt with in the empirical section.

3.2 Tariff and trade

To estimate the gravity equation of trade in intermediate inputs in (13), I collect trade and tariff data for HS6-digit car parts from UN Comtrade and the World Integrated Trade Solution (WITS). 26 categories are identified for car parts including engines, transmissions, brake system, steering and suspension components, electrical equipments, seats and other parts. Final good is restricted to passenger cars.

Figure 1 reports distributions of cars and car parts effectively applied tariffs across country-pair-year observations, excluding a large number of zero tariffs. Effectively applied tariffs would be the MFN rates if a country pair does not form RTA and preferential tariffs otherwise. Variation in tariffs takes into account the phase-out schedule and two partial scope agreements. As in panel (a),

[8]The recent replacement of NAFTA with USMCA increases RVC threshold to 75%, and also introduces new regulation on labor value content that requires 40-45% of auto content be made by workers earning at least $16 per hour, as well as 70% percent of both the steel and aluminum used in car production must originate within the region. However, the two new requirements are not commonly used across RTAs. I ignore clauses other than RVC for now but acknowledge that my measurement of stringency could be at the lower bound.

[9]As global value chain becomes more fragmented, production of non-originating intermediates could involve the use of originating materials as inputs. However, the value flow back home through imported foreign intermediates is not counted intra-RTA. So technically from the global value chain perspective, RoOs are more restrictive than it appears to be.

[10]The RVC for light vehicles was first set to be 50% during 1994-1998, and then modified to be 56% in 1998-2002. It is finally raised to 62.5% from 2002 until the recent replacement to USMCA.

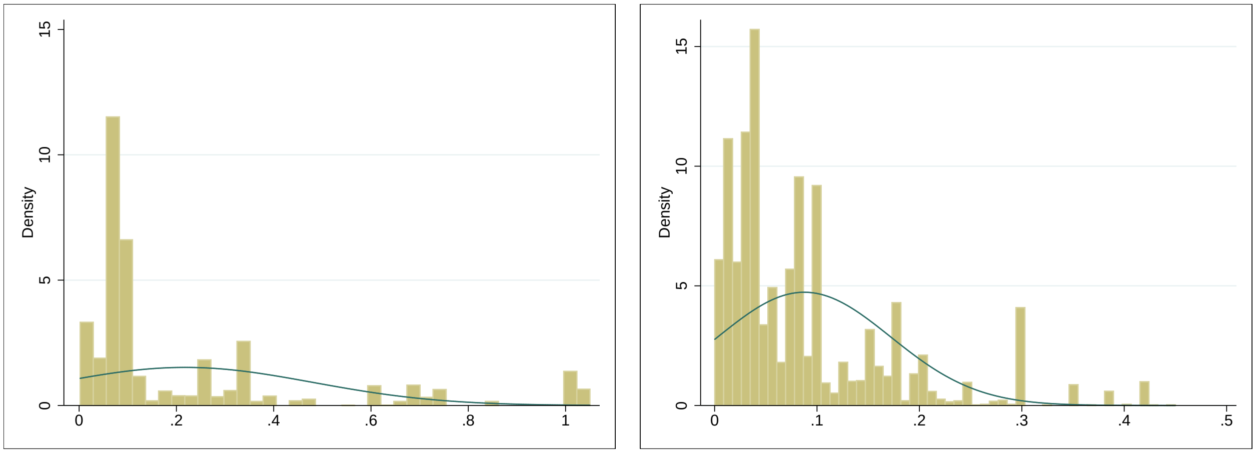
Table 1: Description statistics on RTA and RVC

	EIF Year	Car RVC (%)
North American Free Trade Agreement (NAFTA)	1994	62.5[10]
pan-Euro-Mediterranean cumulation system / PEM Convention	1997	60
EU - Mexico	2001	60
EFTA - Mexico	2002	40
Accession of China in Asia Pacific Trade Agreement (APTA)	2002	45
Japan - Mexico	2005	65
ASEAN - China	2005	40
EFTA - South Korea	2007	55
Japan - Thailand	2008	40
ASEAN - South Korea	2008	40
ASEAN - Japan	2009	40
ASEAN - India	2010	35
EFTA - Canada	2010	50
India - MERCOSUR	2010	60
India - South Korea	2010	40
India - Japan	2012	50
EU - South Korea	2012	55
South Korea - U.S.	2012	55
South Korea - Turkey	2013	55

Note: Pan-Euro-Mediterranean cumulation system is based on a network of Free Trade Agreements having identical origin protocols with contracting parties including the **EU**, EFTA, **Turkey**, and participants in the Barcelona Process, and others. Four other FTAs are part of PEM Convention and not separately listed above. EFTA countries consist of **Iceland**, **Norway**, Switzerland, Liechtenstein during 2000-2014. NAFTA countries are the **US, Canada and Mexico**. Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, **Thailand**, and Vietnam form ASEAN. MERCOSUR comprises Argentina, **Brazil**, Paraguay and Uruguay. Countries that are bolded in these organizations, as well as **China, Japan, South Korea, and India** are included in the regression analysis of this paper.

India has over 100% tariff on passenger cars, followed by China at around 86% before joining the WTO but gradually lowering the tariff thereafter. The MFN tariff on passenger cars for Thailand is as high as 74%, while that for Brazil and Mexico is around 30% to 45%. Countries such as the US and Canada have low rate at about 1% - 5%, and Japan zero tariff although the high automobile standards impede foreign cars from stepping into the market. Car parts generally face lower tariffs compared to what are imposed on finished cars due to tariff escalation. China had relatively high tariff on auto parts at 45% before becoming a member of the WTO and reduced it to around 10% until 2014. Thailand and India are at the top tier of countries which set high MFN rates on parts at 30% - 40%, followed by Brazil and Mexico at around 20%. Tariffs on parts in the US, Canada and Japan are largely approaching zero.

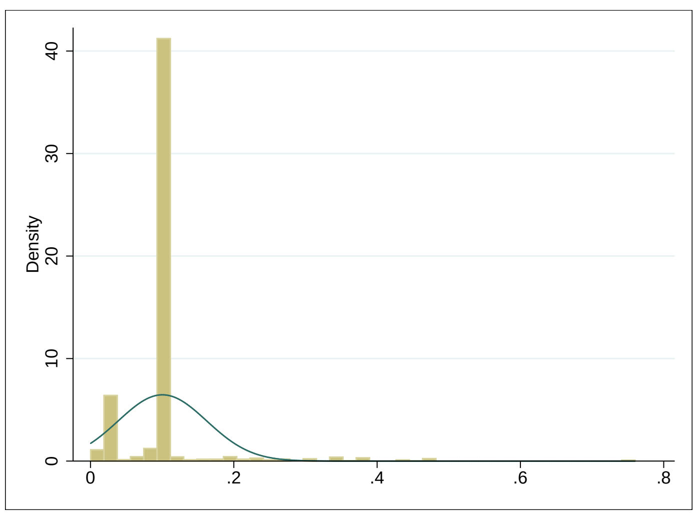
Figure 1: Distribution of effectively applied tariff



(a) Passenger cars (b) Car parts

Unlike applied tariffs on cars, Figure 2 shows preferential margins defined as the difference between the MFN and preferential tariffs are not as dispersed but highly concentrated at 10%. It is consistent with the fact that most MFN rates on passenger cars are around 10% as presented in Figure 1, panel (a).[11] Countries that are located at the thin right tail are India, Mexico and a few small European economies who witness substantial tariff decline after forming RTAs.

Figure 2: Distribution of preferential margin on passenger car

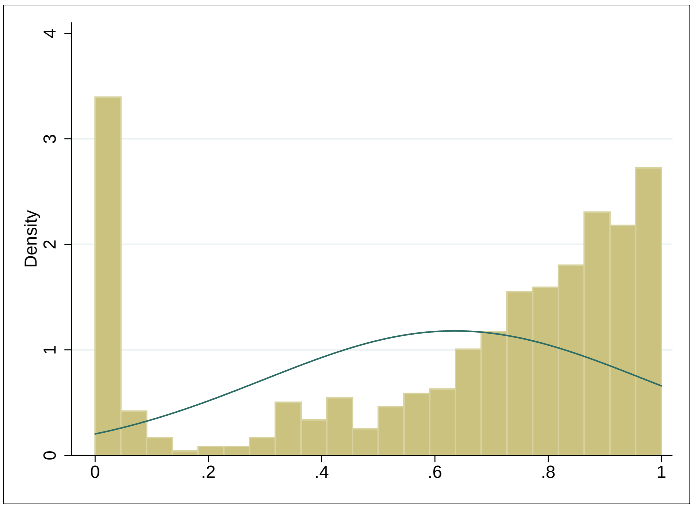


Although the model does not explicitly solve firms' decisions on export of cars, equation (10) incorporates the market demand within RTA in determining import of intermediates at the firm

[11]Figure 1, panel (a) and Figure 2 are not exactly the same because phase-out tariff schedule and PSAs are included in the former but not the latter. The difference between MFN and each year's phase-out tariff is included when plotting Figure 2.

level. Theoretically, firms are more likely to obey rules and source pars internally if they mainly serve the markets within RTA. In practice, I construct the share of intra-RTA trade over total export in cars to test the hypothesis.[12] Along the distribution of intra-RTA export share in Figure 3, China, India, Thailand and Japan who are at the lowest bound around zero have fewer trade agreements signed with the rest of countries in my sample, whereas they are major car exporters worldwide. On the contrary, Mexico and some small European countries almost entirely rely on export to NAFTA countries and the EU. The US and Germany are at the mean where 60% of their car exports flow to RTA members.

Figure 3: Distribution of cars export share within RTA



3.3 Part-level data

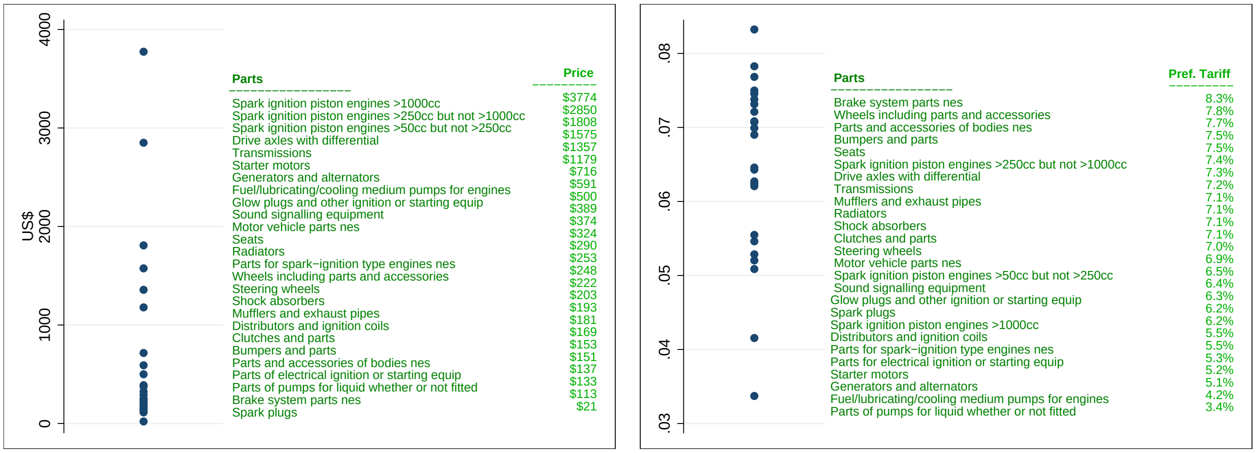
To estimate equation (14), I introduce parts characteristics, namely unit prices, to be interacted with the RVC level in the analysis. The unit price at the HS6-classified auto part is computed as the sum of total value traded by the US divided by the corresponding physical volume based on the primary quantity unit measured at HS10 digit before averaging to HS6. Average prices across origins and years are used to test for any heterogeneity in effects of RoO by the nature of each part.

Figure 4 panel (a) shows that most parts cost below $500, before jumping to thousand-dollar engines, transmissions and starter motors. Brake system and spark plugs are the least costly parts when assembling a car.[13] Panel (b) visualizes tariffs across parts averaging over country pairs and years. Compared to Figure 1, much of the variation in tariffs of auto parts stems from country pairs and years instead of the product dimension.

[12]Production of cars that serves the domestic market (i.e. trade with itself) is not included in the measurement because it is not subject to RoOs.

[13]Price for spark plugs are denoted at 6 units to fit a common car's usage.

Figure 4: Heterogeneity in car parts



(a) Unit price

(b) Applied tariff[14]

3.4 Bilateral accessibility

The last set of data needed for estimating the gravity equation are the standard explanatory variables, including distances, whether two countries are adjacent or share a common language, as non-price cost shifters. These variables have been shown in past literature to matter for trade flows.

Another variable controlled for is customs union (CU). Unlike FTAs, member states in a CU would have a common external tariff in which case trade deflection is eliminated. Therefore, the rationale for having rules of origin is largely weakened, which is why RoOs are typically absent from CU arrangements.[15] In the last year of my sample 2014, 28 EU countries and therefore 756 out of 1560 bilateral trading pairs belong to a customs union.[16] For the whole sample, about 35% of observations are part of a CU, 25% belong to a FTA or PSA, and the rest do not form any regional trade agreements. I include a customs union dummy in the following regression analysis to avoid omitted variable bias.

4 Empirical Analysis

The primary goal of this paper is to verify whether rules of origin create trade diversion in intermediate goods from non-RTA countries to member states using an example of 26 types of auto parts. With time dimension added, I specify the implicit trade friction from RoOs as a function of

[14]Average applied tariffs exclude zero-tariff observations to be comparable with Figure 1.

[15]See Georges (2008) for the effects of removing RoO by a hypothetical move from NAFTA to CU. They also mentioned that the European Commission set preferential RoOs for exceptions to the principle of free circulation.

[16]Intra-national trade data is excluded because production data for each of the 26 auto parts is not available.

observables between country i and ℓ, denoted $\mathbf{R}_{i\ell t}$. It includes indicators of whether the two countries belong to a customs union or connected by a regional trade agreement, and interactions with the regional value content requirements. The non-price trade costs are a function of distance, and a time-invariant vector of dummies describing the bilateral relationship, denoted $\mathbf{D}_{i\ell}$. *Ad-valorem* tariff for part j is $\tau_{ji\ell t}$. Explicitly, they are

$$r_{i\ell t} = \exp(\mathbf{R}'_{i\ell t}\beta^r), \;\; d_{i\ell} = \exp(\mathbf{D}'_{i\ell}\beta^d), \;\; \tau_{ji\ell t} = 1 + t_{ji\ell t},$$

where β^r and β^d are vectors of trade cost parameters.

The gravity trade equation (13) describing product trade flow between countries can be transformed to its estimable form,

$$X_{ji\ell t} = \exp\left[\text{FE}_{j\ell t} + \text{FE}_j + \text{FE}_{it} - \theta\mathbf{R}'_{i\ell t}\beta^r - \theta\mathbf{D}'_{i\ell}\beta^d - \theta\ln(1 + t_{ji\ell t}) + \epsilon_{ji\ell t}\right], \tag{15}$$

where the importer-part-year fixed effect is $\text{FE}_{j\ell t} = \ln\left(F_\ell \Omega_{\ell t} \Phi_{\ell t}^{-\frac{\alpha}{(1-\alpha)\theta}} \Phi_{j\ell t}^{\frac{\alpha}{(1-\alpha)\theta}-1}\right)$, the exporter-year fixed effect is $\text{FE}_{it} = -\theta\ln(w_{it})$, and the part fixed effect is $\text{FE}_j = \theta\ln(\psi_j)$.[17] The equation is estimated using Poisson Pseudo Maximum Likelihood (PPML) for its consistency and capability of incorporating zeros as clearly explained in Silva and Tenreyro (2006) and Head and Mayer (2014).

Two issues emerge from the data. One is that the production data for HS6-digit car parts across countries and years is not readily available, which means the intra-national trade is missing from the panel. It could cause biases in the estimation of the effect of distance on trade when internal distances are not accounted for. What's more concerning is that the impact of RTAs can be downward biased when RTAs divert trade from domestic to foreign sales.[18] However, our target of interest, the effect of RoO restriction, may survive the problem because use of content from the country itself or its RTA partners is treated the same to meet the rule. So there is no further distortion between intermediate trade diverted to the importer itself or other RTA members unless cumulation rules other than full cumulation is applied.[19] The other is that as mentioned in Section 3.1, RVC thresholds are highly concentrated at 60% due to the common practice by the

[17] I assume the product fixed effect does not vary by year because technology in producing cars is stable in years and the marginal product ψ of a part is not likely to vary.

[18] See Yotov et al. (2016), chapter 1 for more discussion on including intra-national and international trade in the estimation of structural gravity.

[19] Cumulation rules define the geographic area from which inputs can be sourced without losing its originating status. It can follow full cumulation, diagonal cumulation or bilateral cumulation. Under full cumulation, intermediates from RTA partners can be used unconditionally. Diagonal cumulation is that firms can import intermediate goods from any RTA members as long as the intermediates are produced under the same rules. Bilateral cumulation is the most restrictive where firms can only import intermediates from itself or produced in the importing country. See Bombarda and Gamberoni (2013) for more details. Throughout the paper, I assume full cumulation is used.

EU countries. In fact, over 20% of the observations have RVC at 60% and that is about 90% of those that form a RTA, which leads to a collinearity problem when both the RVC and RTA dummy are included in a regression. To separately identify the RoO effect, I replace the continuous RVC variable to a group of dummies – country pairs that are subject to RVC below 60%, equal 60%, and above 60%. It is as if I compare effects under different quantiles. I hereby interpret the estimated coefficients with great caution.

Table 2 reports the main results. Throughout the five columns, estimates on the standard gravity variables have the expected direction but smaller magnitude than what have been found by the literature. Distance has the elasticity around -0.6 instead of the benchmark -1 reported in Head and Mayer (2014), contiguity around 0.35 compared to 0.6, and the estimated effect of common language is not significant. The downward biases are likely to be caused by the missing intra-national trade in the sample. Customs union which is the EU country dyads here has a much larger effect on trade. Using the mean coefficient at 1.56, it implies that customs union entered into force increases trade in car parts by more then threefold on average.[20] Other RTAs increase trade by around 274 percent based on the coefficient in column (1) which is at the higher end among past findings. The trade elasticity $-\theta$ identified through tariffs variation is consistent with the literature between -4 to -5, although the effect is weakened when adding more RTA interactions in columns (4) and (5).

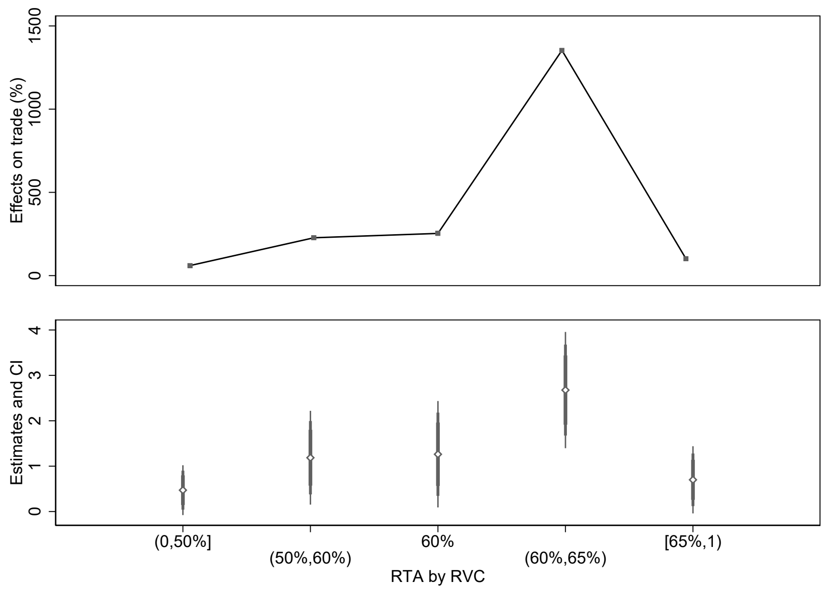
Now, let's focus on our parameter of interest, the effect of RoOs. Given the limited variation across RVC thresholds in the sample RTAs, column (2) presents undesirable results which validates the existence of the collinearity problem. I deal with the issue by grouping the RVCs into three range. Column (3) shows that import of intermediates from RTA partners is 130% larger than importing from third countries when RVC is below 60%. The impact is equivalent to removing 19% of the *ad-valorem* tariff.[21] As the RVC is higher, a 60% content rule amounts to the equivalent of a 28% tariff on auto parts and higher than 60% implies a 53% equivalent tariff effect. The escalating trade diversion effects suggest that more restrictive RoOs amplify the shift of intermediates from outside to the RTA region, holding everything else among RTAs in the three groups the same. Column (4) employs the same specification as column (3) but substitutes product-origin-year fixed effects for the separated product fixed effects and origin-year fixed effects. Results are quite robust. To further decompose the effects of RoO, I run column (5) where there are five groups of RTAs defined by their respective RVC level. Figure 5 visualizes the coefficients, their confidence intervals and effects on intermediates trade. Interestingly, we observe a humped shape relationship between the degree of trade diverted and RoO restrictiveness. More imports of intermediates occur

[20]For an indicator variable, the effect is interpreted as $\exp(1.56) - 1 \approx 3.76$.

[21]The effect is calculated by $(\exp(0.831) - 1) \times 100\% \approx 129.6\%$ and tariff equivalent as $(\exp(0.831/4.705) - 1) \times 100\% \approx 19.32\%$.

within the RTA until the RVC hits a peak at somewhere between 60% to 65%, supporting the argument that firms would reallocate more inputs intra-RTA to satisfy the tightened content rule and maintain the originating status of their final output. However, beyond 65%, increase in trade of car parts within the RTA declines sharply. Although the endogenous adjustment of firms changing from compliers to defiers is not explicitly modeled in the previous theoretical section, the empirical results here are a mix of intensive and extensive margin. The RVC requirement beyond 65% is too stringent for firms to comply, and they may relocate elsewhere offsetting the trade diversion effects of RoO. The results resonate with the Laffer curve modeled in Head et al. (2021) where stricter content requirements initially expand production but eventually contract it, but instead of performing a simulation exercise, I show the nonlinear effects of RoO with real data.

Figure 5: Trade effects of RTAs under different RVC



As an extension of our baseline results, I further investigate what channels contribute to the RoO effects and whether there is any heterogeneity depending on firms' export status and parts imported. Building on the preferred estimates in column (3) of Table 2, I interact the RTA-RVC group dummies with three more variables, namely the share of export within the RTA, the preferential margin on cars exporting to other RTA members, and the average price of auto parts. First, when RTA member countries are important markets for car exporters at country ℓ, firms would benefit from complying the rules and enjoy the preferential treatment. Hence, keeping the RVC constant, greater proportion of intra-RTA trade in final goods implies more firms would become compliers and overall import more intermediates regionally. Results in column (1), Table 3, verify my hypothesis. For RTAs with RVC either below or above 60%, sourcing of car parts by country

ℓ from its RTA partner i increases significantly with the share of cars exported by ℓ to the same RTA in its total export.[22] The effect disappears when RVC is equal to 60% because they are mainly agreements of a third country and the EU where goods are freely circulated.

The second refinement comes from preferential tariff margin of exporting final goods. Car exporters incline to abide by the rules when the benefit from a higher tariff margin dominates the cost of sourcing from inefficient suppliers. Therefore, trade diversion is stronger with preferential margin in car exports. For RTAs with high content requirements, we observe such effect in column (2). Nevertheless, it is not significant when RoOs are generous and has unexpected sign when RVC is 60%. The negative effect of preferential margin at 60% is again attributed to EU and EFTA countries where parts are already freely traded. When they sign RTA with a country outside of Europe (for example, Mexico), the country who experiences large tariff reduction does not source as much European parts as European countries themselves. Comparing column (2) to (1), another observation is that the intensive margin on tariff reduction does not have enough power in explaining trade diversion of inputs as the extensive margin effect of car exports share. Hence, in column (4) when I include all three sets of interactions, the effects of intra-RTA export share remains to be significant but not those of preferential margin on cars.

Lastly, equation (14) sets the foundation for testing whether RoOs have the same effect on different car parts. Observing column (3), I do not find systematic pattern across parts with different prices. There can be two counteracting forces. On one hand, sourcing decision tends to be pivotal for expensive parts and should be sourced within the RTA region. On the other hand, the buyer-seller relationship may be more sticky for expensive parts. For example, suppliers outside of the RTA offer a bigger discount or the part has higher specificity. The mixed effects will not be clearly identified without firm-level data.

The last column in Table 3 combines all three forces. Results stay consistent with those from separately added variables. In addition, with modifiers to the RoO effects, the RTA$\times$RoO interactions lose their significance although the signs are still as expected.

5 Conclusions

This paper opens up the RTA black-box by separating the effects of tariff reduction from rules of origin. Specifically, I estimate the distortive effect of rules of origin on intermediate goods trade by exploring a particular dimension of sourcing restrictions, regional value content. A clear takeaway from results by applying the framework to the automotive industry is that car assemblers

[22]One reason that could alter the interpretation of results in export share is that consumer have taste preference towards final cars that assembled using domestic parts. If then, increasing intra-RTA export share does not increase imports of car parts through firms' responses to RoO but through the demand side. However, whether consumers have perfect knowledge on car parts used for assembly is an empirical question.

do reformulate sources of parts when facing more restrictive rules of origin. When RVC is above 60%, RTA is equivalent to a 53% *ad-valorem* tariff on the affected intermediate goods. The trade diversion effect of RoOs, however, is not linear but following a humped shape. The increase in import of intermediates within a RTA first rises with more restrictive content rules but eventually falls down when more firms becoming RoO defiers.

Going beyond the main effects of RoOs, I test three channels in which RoO takes effect heterogeneously: the share of export to RTA region in total export of final goods, preferential margin of final goods subsidized by RTA members, and the unit price of intermediates. Car exporters who target RTA markets find RoOs matter, and thus trade diversion is stronger with larger intra-RTA car export. The other two channels, preferential margin on cars export and parts' prices, do not exhibit significant and robust effects. More disaggregated firm-level data is necessary to identify the mixed forces in these two.

Theoretically, I build a multi-country and multi-product sourcing model to study where and how many inputs firms import. Rules of origin is incorporated in the framework as a *ad-valorem* trade costs on intermediates. It derives a gravity trade equation at product level that becomes handy in estimation. This is not a full-fleshed characterization of RoOs since I do not model export decisions of firms and firms' choices of whether to comply with the rules of not. There should be future attempts on adding these elements to the model and estimate it structurally with finer data.

It would also be interesting to study the RoO effects along the entire value chain. When goods cross borders multiple times in a fragmented production process, trade costs can accumulate and compound before the goods are sold for final consumption. Therefore, production which is labeled non-originating can be very costly. The aspects of global value chain provide a full agenda for future research.

Despite having limitations, this paper contributes to the existing literature by examining the effect of rules of origin across a wide span of trade agreements. It also provides guidance for policy makers in setting the optimal regional value content threshold by providing evidences on its nonlinearity. This paper serves as an exploration of the optimal RVC, while leaving future work to build upon.

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Appendix

A Derivation of firm's conditional inputs sourcing

In this Appendix, I provide more details on assembler's behavior conditional on sourcing location. Notice first that by solving first order condition of equation (4), I obtain the following optimal decision of parts quantity:

$$x_{j\omega}^* = \left\{ A_\omega^{1-\rho}\theta_\omega^\rho \rho \left[\int_0^1 (\psi_j x_{j\omega}^*)^\alpha dj \right]^{\frac{\rho}{\alpha}-1} \frac{\psi_j^\alpha}{c_{j(i^*)\omega}} \right\}^{\frac{1}{1-\alpha}}. \tag{A-1}$$

Let $Z_{j\omega}^* = \int_0^1 (\psi_j x_{j\omega}^*)^\alpha dj$. Plugging this expression into the above $x_{j\omega}^*$ and transform it into a function of $Z_{j\omega}^*$ delivers the following,

$$Z_{j\omega}^* = \int_0^1 \psi_j^\alpha \left(A_\omega^{1-\rho}\theta_\omega^\rho \rho (Z_{j\omega}^*)^{\frac{\rho}{\alpha}-1} \frac{\psi_j^\alpha}{c_{j(i^*)\omega}} \right)^{\frac{\alpha}{1-\alpha}} dj.$$

Solving this equation, it's straightforward to verify

$$Z_{j\omega}^* = \rho^{\frac{\alpha}{1-\rho}} A_\omega^\alpha \theta_\omega^{\frac{\alpha\rho}{1-\rho}} \left[\int_0^1 \left(\frac{\psi_j}{c_{j(i^*)\omega}} \right)^{\frac{\alpha}{1-\alpha}} dj \right]^{\frac{1-\alpha}{1-\rho}}. \tag{A-2}$$

Lastly, substitute (A-2) back to (A-1), from which we can conclude the optimal $x_{j\omega}^*$ is given by equation (5).

B Derivation of country-level sourcing decisions

From equation (10), I need to integrate it to the country level over a set of varieties. Denote $u = \varphi_\omega \delta_\omega^\rho$ and $\underline{u}$ is the corresponding lower bound. Notice that the distribution of $v_{j\omega}$ and V_ω is invariant to ω, therefore integration of these variables can be replaced by the integration over v, multiplied by the measure Ω_ℓ. $G(v)$ is the distribution in equation (8). $G(u)$ is the Pareto distribution with shape parameter η. Then, we have

$$\begin{aligned}
X_{j\ell} &= \rho^{\frac{1}{1-\rho}} EP^{\frac{\rho}{1-\rho}} \int_{\omega\in\Omega_\ell} (\varphi_\omega \delta_\omega^\rho)^{\frac{1}{1-\rho}} \left(v_{j\omega}^*\right)^{\frac{\alpha}{1-\alpha}} V_\omega^{\frac{\rho-\alpha}{(1-\alpha)(1-\rho)}} d\omega \\
&= \rho^{\frac{1}{1-\rho}} EP^{\frac{\rho}{1-\rho}} \left(\int_{\underline{u}}^\infty u^{\frac{1}{1-\rho}} dG(u)\right) \times \Omega_\ell \times \int_{\omega\in\Omega_\ell} \left(v_{j\omega}^*\right)^{\frac{\alpha}{1-\alpha}} V_\omega^{\frac{\rho-\alpha}{(1-\alpha)(1-\rho)}} d\omega \\
&= \frac{\eta\rho}{\eta(1-\rho)-1} F_\ell \Omega_\ell \int_{\omega\in\Omega_\ell} \left(v_{j\omega}^*\right)^{\frac{\alpha}{1-\alpha}} V_\omega^{-\frac{\alpha}{(1-\alpha)}} d\omega \\
&= \frac{\eta\rho}{\eta(1-\rho)-1} F_\ell \Omega_\ell \left(\int_0^\infty v^{\frac{\alpha}{1-\alpha}} dG(v)\right) \times \left[\int_0^1 \int_0^\infty v^{\frac{\alpha}{1-\alpha}} dG(v) dj\right]^{-1}. \qquad \text{(A-3)}
\end{aligned}$$

Using the derived distribution of v, we have

$$\int_0^\infty v^{\frac{\alpha}{1-\alpha}} dG(v) = \Gamma\left(1 - \frac{\alpha}{(1-\alpha)\theta}\right) \Phi_{j\ell}^{\frac{\alpha}{(1-\alpha)\theta}}. \qquad \text{(A-4)}$$

Therefore, substituting (A-4) back to (A-3) obtains equation (12).

Table 2: Baseline results

Dep. Var	parts export$_{ji\ell t}$, PPML				
	(1)	(2)	(3)	(4)	(5)
ln dist$_{i\ell}$	-0.652^{a}	-0.634^{a}	-0.593^{a}	-0.588^{a}	-0.496^{a}
	(0.105)	(0.111)	(0.119)	(0.121)	(0.115)
contiguity$_{i\ell}$	0.398^{a}	0.382^{a}	0.344^{b}	0.356^{b}	0.266^{c}
	(0.140)	(0.146)	(0.172)	(0.152)	(0.152)
language$_{i\ell}$	0.034	-0.006	0.010	-0.022	0.081
	(0.237)	(0.237)	(0.240)	(0.214)	(0.225)
CU$_{i\ell t}$	1.520^{a}	1.560^{a}	1.469^{a}	1.529^{a}	1.740^{a}
	(0.262)	(0.272)	(0.385)	(0.386)	(0.326)
ln (1+parts tariff$_{ji\ell t}$)	-4.093^{b}	-4.321^{a}	-4.705^{a}	-3.830^{b}	-2.362
	(1.984)	(1.633)	(1.783)	(1.911)	(1.690)
RTA$_{i\ell t}$	1.320^{a}	-1.548			
	(0.277)	(1.379)			
RTA$_{i\ell t}\times$ RVC$_{i\ell t}$		5.003^{c}			
		(2.784)			
RTA$_{i\ell t}$ $\times$ 1(RVC$_{i\ell t}$ $<$60%)			0.831^{a}	0.875^{a}	
			(0.113)	(0.131)	
RTA$_{i\ell t}$ $\times$ 1(RVC$_{i\ell t}$ =60%)			1.177^{a}	1.213^{a}	
			(0.385)	(0.389)	
RTA$_{i\ell t}$ $\times$ 1(RVC$_{i\ell t}$ $>$60%)			1.994^{a}	2.074^{a}	
			(0.519)	(0.543)	
RTA$_{i\ell t}$ $\times$ 1(RVC$_{i\ell t}$ $\leq$50%)					0.471^{a}
					(0.167)
RTA$_{i\ell t}$ $\times$ 1(50%$<$RVC$_{i\ell t}$ $<$60%)					1.186^{a}
					(0.314)
RTA$_{i\ell t}$ $\times$ 1(RVC$_{i\ell t}$ =60%)					1.263^{a}
					(0.356)
RTA$_{i\ell t}$ $\times$ 1(60%$<$RVC$_{i\ell t}$ $<$65%)					2.676^{a}
					(0.389)
RTA$_{i\ell t}$ $\times$ 1(RVC$_{i\ell t}$ $\geq$65%)					0.699^{a}
					(0.225)
Observations	607971	607971	607971	592693	607971
R^2	0.884	0.885	0.886	0.922	0.888

The parts are defined at HS 6-digit level and their export in US dollar current value. It includes international trade flow between 40 countries from 2000 to 2014, but not intra-nation due to missing parts production data. All columns except (4) include product, origin-year, and destination-product-year fixed effects. Column (4) includes fixed effects for origin-product-year and destination-product-year. Standard errors are multi-clustered at origin, destination, and product level in parenthesis. Significance levels: ^{c} p<0.1, ^{b} p<0.05, ^{a} p<0.01.

Table 3: Heterogeneous RoO effects

Dep. Var	parts export$_{ji\ell t}$, PPML			
	(1)	(2)	(3)	(4)
ln dist$_{i\ell}$	-0.497^{a}	-0.593^{a}	-0.592^{a}	-0.498^{a}
	(0.113)	(0.121)	(0.119)	(0.113)
contiguity$_{i\ell}$	0.342^{b}	0.328^{b}	0.345^{c}	0.330^{b}
	(0.154)	(0.164)	(0.187)	(0.168)
language$_{i\ell}$	0.015	-0.010	0.010	0.013
	(0.240)	(0.249)	(0.246)	(0.245)
CU$_{i\ell t}$	1.754^{a}	1.439^{a}	1.471^{a}	1.744^{a}
	(0.334)	(0.402)	(0.385)	(0.344)
ln (1+parts tariff$_{ji\ell t}$)	1.087	-5.362^{a}	-4.692^{a}	0.669
	(2.205)	(1.865)	(1.800)	(2.182)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ <60%)	0.505^{a}	0.912^{a}	1.186^{a}	1.098^{b}
	(0.084)	(0.182)	(0.391)	(0.461)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ =60%)	1.171^{a}	1.341^{b}	1.120	1.571
	(0.422)	(0.530)	(1.060)	(1.285)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ >60%)	1.325^{a}	1.442^{b}	1.944^{b}	0.978
	(0.472)	(0.590)	(0.828)	(0.864)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ <60%) × expsh$_{\text{RTA}(i)\ell t}$	0.084^{a}			0.099^{a}
	(0.017)			(0.019)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ =60%) × expsh$_{\text{RTA}(i)\ell t}$	0.021			0.019
	(0.020)			(0.021)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ >60%) × expsh$_{\text{RTA}(i)\ell t}$	0.070^{a}			0.071^{a}
	(0.013)			(0.016)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ <60%) × expmargin$_{\text{RTA}(i)\ell t}$		-1.994		-4.882
		(3.479)		(3.519)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ =60%) × expmargin$_{\text{RTA}(i)\ell t}$		-3.198^{a}		-4.806^{a}
		(1.166)		(1.409)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ >60%) × expmargin$_{\text{RTA}(i)\ell t}$		4.092^{c}		2.346
		(2.360)		(2.165)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ <60%) × ln (part price$_{j}$)			-0.057	-0.076
			(0.064)	(0.069)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ =60%) × ln (part price$_{j}$)			0.009	0.003
			(0.143)	(0.151)
RTA$_{i\ell t}$ × 1(RVC$_{i\ell t}$ >60%) × ln (part price$_{j}$)			0.008	-0.003
			(0.105)	(0.112)
Observations	604929	604929	604929	604929
R^2	0.888	0.886	0.886	0.888

All columns include product, origin-year, and destination-product-year fixed effects. Standard errors are multi-clustered at origin, destination, and product level in parenthesis. Subscript RTA$(i)\ell$ refer to the RTA both country i and ℓ belong. expsh$_{\text{RTA}(i)\ell t}$ is country ℓ's share of car export to the RTA partners over ℓ's total car export. expmargin$_{\text{RTA}(i)\ell t} = \ln(1 + \text{MFN tariff}_{\text{RTA}(i)\ell t} - \text{pref tariff}_{\text{RTA}(i)\ell t})$ is the preferential margin on country ℓ's car when exporting to the RTA partners. Unit value of part j is derived as described in Section 3.3. Significance levels: ^{c} p<0.1, ^{b} p<0.05, ^{a} p<0.01.