Rules of Origin and Automobile 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). FTAs distort firms sourcing decisions internationally through preferential tariffs and rules of origin (RoOs), a set of regional value content (RVC) criterion to ensure that goods are originated from member countries to be granted preferential treatment when exporting within the FTA. This paper unpacks the effects of FTAs and distinguishes the intermediate trade elasticities with respect to RoOs and tariffs, focusing on the automobile industry. Decisions of how much car parts to acquire and which supplier location to select for each part are modeled for car assemblers. With the derived gravity trade equation, the estimation identifies significant diversion in sourcing induced by high RVC requirement, to an extent more than a direct tariff reduction. However, RVC below 60% tends not to be binding. The impacts of RoOs are further heterogeneous depending on export destinations of final goods, the degree of preferential treatment and the value of inputs.

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1 Introduction

In 2016, a set of free trade agreements (FTAs) have drew unprecedented attention led by the proposed Trans-Pacific Partnership (TPP) and the heated US presidential election. TPP, as a landmark agreement which covers 37% of the world GDP and 24% of the world total exports, not only commits to major tariff reduction amongst the parties but also targets a set of far-reaching integration issues that range from goods and services to e-commerce, environment and intellectual property rights[1]. However, when it comes to sensitive sectors, such as automobile industry, TPP faces vigorous opposition in the case where regional value content on duty-free vehicles drop from 62.5% in North American Free Trade Agreement (NAFTA) to 45%. Such controversy sheds light on an independent commercial policy instrument which used to be less transparent: preferential rules of origin (RoOs). It functions as a set of rules to determine the origin of products and whether products can be granted preferential tariff treatment. As such, RoOs were seen to play a "supportive" role for the implementation of a more direct channel historically. 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 is crucial in reshaping firms' input allocation by defining the nature of a good.

Legal complexity and inconformity of the rules presents a major challenge in measuring the restrictiveness of rules of origin across various industries. In fact, the practice with regard to the RoOs varies across products and governments, with some defined in terms of change in tariff classification, others the regional value content percentage (RVC) criterion and yet others the requirement of manufacturing or processing operation. I therefore study a single industry, cars, where global sourcing is prevalent and, most importantly, regional value content criterion is mostly harmonized and applied across FTAs. This allows me to rank the FTAs according to the threshold share of value originating from member states out of the entire value of a car, which regulates to what extent a car can source its parts all around the world. Having restrictiveness of RoOs imposed on cars, I can distinguish the impacts of free trade agreements on auto parts through two channels, namely variation in tariffs on parts and required value of originating parts on final car. Strong functional forms are established to make estimation tractable and model car manufacturer's sourcing decision for parts directly.

[1] Data from the World Banks World Development Indicators database, `http://databank.worldbank.org/data/reports.aspx?source=2&Topic=21#` (accessed on October 19, 2016).

A natural extension based on the estimated effect of RoOs on auto parts trade is whether different parts, car exporting destinations and magnitude of preferential benefits earn homogeneous results. Rules of origin impose restrictions on car manufacturer's sourcing decisions. A final car producer face the trade-off being whether to enjoy the preferential tariff when exporting car to FTA member countries or the low cost parts sourced from any supplier particularly those from non-members. When preferential margin is high, the benefit of complying RoOs will outweigh violating them and vice versa. RoOs thus constrain one type of firms which export mainly to the FTA member countries even tighter than the rest. And moreover, for those that are more concerned about RoOs, sourcing decision is likely to be pivotal for parts whose cost share in a final car is high, which leads to a more elastic demand compared to trivial parts. Nevertheless, in fact, this may not be true if enough relationship stickiness are provided to expensive parts, such as high discount from non-member suppliers. In addition, none of these RoOs' effects will function if the rules are not binding. This paper also attempts to empirically explore the optimal and binded rules of origin in the form of RVC along this dimension.

The quantitative framework employed in this paper combines a CES (constant elasticity of substitution) aggregator in both consumer demand and final-good production function that integrates inputs as in Antràs and Chor (2013) and Alfaro et al. (2015), which mostly build upon Acemoglu et al. (2007). Sourcing decision based on input suppliers' cost structure is adapted from Eaton and Kortum (2002) via Head and Mayer (2016). Important contributors to model multinational firms' sourcing decisions include Antràs (2003, 2005) and Antràs and Helpman (2003, 2006), but none of those directly measures the effect of trade agreements due to global sourcing. Meanwhile, there is another strand of literature where specifically examines the welfare impacts of trade relationships given the diversity and complexity of these agreements as what Bhagwati and Panagariya (1999) refers as a "spaghetti bowl". The crowds out effect of regional trade agreements (RTAs) was documented as early as in Viner (1950) and Meade (1955). Since 1970s when gravity equation was introduced, numerous studies estimate changes in trade patterns driven by trade agreements, including Baldwin (1994), Eichengreen and Irwin (1995), Feenstra (1998), and Anderson and Van Wincoop (2003). Particularly, the meta-analysis by Cipollina and Salvatici (2010) surveys multiple methodologies and reports the trade elasticity with respect to regional trade agreements having a mean effect of 0.59 and median 0.38. The magnitude is persistent as shown in Head et al. (2013). Recent work tries to unpack the effect of trade agreements through tariff reduction. Head and Ries (2001) decomposes the "border effect" into the tariffs and non-tariff barrier portion in which the latter accounts for 45% to 52% of the total trade cost between Canada and U.S.. Caliendo and Parro (2014) finds that welfare increase induced from tariff reduction is heterogeneous across NAFTA countries and significantly determined by the share of intermediate goods in production. However, neither of these papers reveals what the other factor which systematically affects FTA members is besides lower tariff. Therefore, this paper not only bridges the gap between firm's sourcing decision and effect of FTAs, but also exposes the FTA black-box by explicitly estimating them through multiple channels, particularly focusing on changes in rules of origin.

Among studies on rules of origin, much interest has been focused on theoretical framework (Krishna and Krueger (1995); Krueger (1997); Falvey and Reed (2002); Krishna (2005); Ju and Krishna (2005)) as well as their measurement and implementation (Estevadeordal (2000); Estevadeordal and Suominen (2006)). Empirical works, however, are limited. The most closely related paper to my work is Conconi et al. (2016) in which they use difference-in-difference to show RoOs on final goods reduce imports of intermediate goods to Mexico from non-NAFTA countries by around 30%. Anson et al. (2005) also finds negative impact of RoO on trade flows using country-level gravity equation but ignores input-output linkages in sectoral level and fails to distinguish separate effects of tariff and RoOs. Bombarda and Gamberoni (2013) builds a three-country general equilibrium model to characterize three type of firms, domestic, exporting firms which comply and violate RoOs, as an extension of Melitz (2003). They apply a gravity type estimation as well but focus on the combined effect of RoO and cumulation rule, specifically in the Pan-European Cumulation System zone. Unlike the RoO restrictiveness measurement used in Conconi et al. (2016) that is the number of final goods' sourcing restrictions that apply to an intermediate good, or Estevadeordal (2000) which uses a synthetic index based on the type of rules implemented, this paper differs in using regional value content as a direct cutoff constraint which follows the way theoretical papers have modeled RoO. Therefore, a natural linkage between theoretical and empirical work can be established and substantiate each other.

The first contribution of this paper is to examine rules of origin restrictiveness on car industry for an nearly exhaustive set of free trade agreements since 2000. In contrast to Conconi et al. (2016), Anson et al. (2005), Bombarda and Gamberoni (2013), Carrere and Cadot (2006) and many other earlier empirical works on RoOs which focus on single FTA but multiple products, restricting the scope on product dimension permits a richer estimation across many FTAs to derive a general conclusion. This paper studies a period from 2000 to 2014 and 21 free trade agreements which entered into force before 2014 except those that became inactive before 2000 which are not going to have any effect between out interested time horizon. These FTAs cover 40 major car and car parts trading countries, namely 31 European countries, U.S., Canada, Mexico, Brazil, Japan, South Korea, China, India and Thailand. I am thus able to do a thorough analysis on RoOs at least in the car industry.

A second contribution of the paper is to unpack the effects of free trade agreements through preferential tariff and rules of origin separately. Building on the literature that quantify the aggregate impact of FTAs, this paper finds that the average intermediate trade effect of FTA through higher than 60% regional value content restriction on final goods is around 2.2, while that of a direct tariff reduction on intermediate goods is 1.8. Lowering RVC will dramatically and nonlinearly weaken the effect of FTA to merely 0.3. The results provide evidence that rules of origin on final products are non-negligible and systematically affect intermediates trade flow. The restrictiveness of RoOs as represented by RVC in this paper matters.

Thirdly, the paper contributes to the literature by further refining the impacts of RoO through three channels and provides understanding on firm's heterogeneous response with respect to RoO changes. For firms whose majority of foreign consumers are within FTA region, high RVC makes them shift sourcing choice intra-FTA. Exporters are also more induced to divert intermediates import when both RVC and tariff discrimination are large. Without the condition that RVC meets certain threshold, 60% in this paper, intermediates trade will not be distorted because firms are not binded to the constraint. To the best of my knowledge, this is the first paper to explore the optimal regional value content for RoO to be effective. From the aspect of differentiated inputs, by way of contrast, Ju and Krishna (2005) and other theoretical work assumes FTA-made parts and imported inputs as exogenously given, which in fact should be determined by the firm depending on their relative cost. I empirically testify which type of intermediates are more elastic to RoO changes, but the result is ambiguous with different forces counteracting each other.

The paper continues in four main sections. I first adapt the existing models to include *ad valorem* rules of origin factor. Deriving from the model, trade elasticity can be recovered from the estimating equation. Refinements are then performed to identify heterogeneous effects of RoO.

2 The model

The structure underlying estimating equations is that firms set quantity of cars to be sold in each market based on consumer demand and then make a multinomial decision over the sourcing country for car parts. A firm would ideally source inputs from the supplier offering the lowest input costs. Meanwhile, without loss of generality, assuming this firm exports to other FTA members, it also wants to benefit from the preferential tariff when doing so. The firm in my paper, however, does not have to be exporting firms only. Rules of origin to some extent can be regarded as additional trade cost when sourcing from non-FTA members besides fixed and variable production costs.

2.1 Consumer preferences and demand

Consider a world where final cars belong to a continuum of active firms with each producing a differentiated variety and individuals value the consumption of different varieties of car according to a standard constant elasticity of substitution (CES) aggregator

$$U_n = \left(\int_{\omega \in \Omega_n} (\varphi_{\omega n} \tilde{q}_{\omega n})^\rho d\omega \right)^{1/\rho} \tag{1}$$

with $\rho \in (0,1)$, where $\varphi_{\omega n}$ represents the quality of a car ω produced in country n and $\tilde{q}_{\omega n}$ its consumption in physical units as in Antràs and Chor (2013). Ω_n denotes the set of varieties. Maximizing consumers' utility subject to the budget constraint $\int_{\omega \in \Omega} p_{\omega n} \tilde{q}_{\omega n} d\omega = E$ where E is the total expenditure, it gives rise to the following demand for car variety ω produced in country n:

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

, where $q_{\omega n} \equiv \varphi_{\omega n} \tilde{q}_{\omega n}$ is the quality-adjusted output. $A_{\omega n} > 0$ denotes a function of quality but exogenous to firms. Consumer's demand features $\frac{1}{1-\rho}$ constant elasticity of substitution among final cars.

2.2 Firm's problem conditional on sourcing location

Under the case of complete contracts, car manufacturers paid parts supplier p_j in exchange for x_j amount of compatible inputs j. Production of final goods requires a measure J of continuum inputs following conventional CES function. The quality-adjusted volume of final car production is then given by

$$q_{\omega n} = \theta_{\omega n} \left(\int_{j \in J} (\psi_j x_{inj\omega})^\alpha dj \right)^{1/\alpha} \tag{3}$$

, where $\theta_{\omega n}$ is the productivity parameter of a car in destination market n, ψ_j captures the marginal product of different car parts which is non-negative and continuously differentiable, and the subscript i indicates the sourcing country of inputs. $\alpha \in (0,1)$ is the degree of substitution for different parts in terms of quality. Following Antràs and Chor (2013), inferior quality of certain parts can be offset by high quality in others although mechanically they are all necessary to complete production.

If all suppliers provide compatible inputs under complete contracts in which final-good producer has full control over quantity for all components, equation (2) and (3) imply car manufacturer's optimal input required by solving profit maximization program as follows,

$$\max_{x_{inj\omega}} \pi_{\omega n} = A_{\omega n}^{1-\rho} \theta_{\omega n}^\rho \left(\int_{j \in J} (\psi_j x_{inj\omega})^\alpha dj \right)^{\rho/\alpha} - \int_{j \in J} p_{ij} x_{inj\omega} dj \tag{4}$$

s.t. $p_{ij} x_{inj\omega} - c_{inj} x_{inj\omega} - F_{in} \geq 0$.

Car parts supplier in country i faces delivered unit cost c_{inj} and fixed cost F_{in}, such as cost for establishing relationship with destination market n and advertising expenses. I show in Appendix by solving this problem delivers the optimal choice of input j and firm's realized profit to be

$$x^*_{inj\omega} = \rho^{\frac{1}{1-\rho}} A_{\omega n} \theta_{\omega n}^{\frac{\rho}{1-\rho}} \left(\frac{\psi_j^\alpha}{c_{inj}}\right)^{\frac{1}{1-\alpha}} \left[\int_{j\in J} \left(\frac{\psi_j}{c_{inj}}\right)^{\frac{\alpha}{1-\alpha}} dj\right]^{\frac{\rho-\alpha}{\alpha(1-\rho)}} \tag{5}$$

$$\pi^*_{\omega n} = \rho^{\frac{\rho}{1-\rho}} (1-\rho) A_{\omega n} \theta_{\omega n}^{\frac{\rho}{1-\rho}} \left[\int_{j\in J} \left(\frac{\psi_j}{c_{inj}}\right)^{\frac{\alpha}{1-\alpha}} dj\right]^{\frac{\rho(1-\alpha)}{\alpha(1-\rho)}} - F_{in} J \tag{6}$$

As opposed to Antràs and Chor (2013) but similar to Alfaro et al. (2015), I introduce heterogeneity of ψ_j and c_j across different inputs. Therefore, the quantity required for each intermediate goods depends on the its own ratio of marginal product and cost as well as the aggregated productivity-adjusted cost. Applying the optimal quantity for all J parts, total profit is variable profit deducted by the summation of all fixed costs with productivity-adjusted cost term embedded. Suppliers' participation constraint turns out to be binding, which leaves suppliers with zero profit.

Equilibrium quantity depends on the delivered unit cost of car part j from sourcing country i to market n:

$$c_{inj} = \frac{w_i}{z_{ij}} \tau_{inj} r_{in} d_{in} \tag{7}$$

, where as in Head and Mayer (2016), w_i is a composite index of wages and material prices for car parts production in sourcing country i and z_{ij} is an idiosyncratic TFP term representing part-location heterogeneity. $\psi_j z_{ij}$ follows Fréchet distribution with CDF $\exp((-\psi_j z_{ij})^{-\mu})$.

Besides marginal production cost, delivery of a compatible car part is subject to a set of delivery frictions from i to n including *ad-valorem* tariff on part, $\tau_{inj} = 1 + t_{inj}$, *ad-valorem* rules of origin restriction on final cars, r_{in}, and other non-price factors such as distance that shifts transportation cost, d_{in}. In order to derive a close form solution of the expected trade of car parts in later sections, I assume the *ad-valorem* tariff is same across different car parts, which is also demonstrated not to be an unreasonable assumption provided the fact that standard derivation of tariff across parts for the same country-pair is only 0.005 in the data. Hence, I compress the j subscript in τ_{inj} and use τ_{in} thereafter. Among this three categories of delivery costs, τ_{in} and d_{in} are larger than 1 representing frictions, whereas r_{in} is not necessarily served as increasing cost for all country pairs but may in fact works the opposite when a country pair forms a free trade agreement. Essentially, this paper is interested in quantifying the trade elasticity with respect to r_{in} and cases where r_{in} raises or reduces cost.

Substituting delivered unit cost (7) into the optimal input quantity (5), it leads to

$$x^*_{inj\omega} = \begin{cases} \rho^{\frac{1}{1-\rho}} A_{\omega n} \theta_{\omega n}^{\frac{\rho}{1-\rho}} \left(w_i \tau_{in} r_{in} d_{in}\right)^{-\frac{1}{1-\rho}} \left(\psi_j^{\alpha} z_{ij}\right)^{\frac{1}{1-\alpha}} \left[\int_{j\in J} \left(\psi_j z_{ij}\right)^{\frac{\alpha}{1-\alpha}} dj\right]^{\frac{\rho-\alpha}{\alpha(1-\rho)}} & \text{if } i = i^*_{nj\omega} \\ 0 & \text{otherwise} \end{cases} \tag{8}$$

, where $i^*_{nj\omega}$ is the optimal sourcing country offering lowest price for part j of car model ω in market n.

Expected x depends on the expectation of $\psi_j z_{ij}$. As $\psi_j z_{ij}$ is distributed multivariate Fréchet with scale parameter μ, the conditional expected sales of car part j adjusted for marginal productivity, given the probability of selecting country i as the j supplier is

$$\mathbb{E}[\psi_j x_{inj\omega} \mid i = i^*_{nj\omega}] = \kappa_1 A_{\omega n} \theta_{\omega n}^{\frac{\rho}{1-\rho}} \left(w_i \tau_{in} r_{in} d_{in}\right)^{-\frac{1}{1-\rho}} \mathbb{P}_{i|nj\omega}^{-\frac{1}{(1-\alpha)\mu}} \tag{9}$$

where $\kappa_1 \equiv \rho^{\frac{1}{1-\rho}} \Gamma\left(1 - \frac{1}{(1-\alpha)\mu}\right) \Gamma\left(1 - \frac{\rho-\alpha}{\alpha(1-\rho)\nu}\right)$ and $\Gamma()$ is the Gamma function. Notice that the parameter ν is coming from the marginal density of a joint Fréchet distribution as showed in Hougaard (1986). This conditional expectation is a multiplication of destination market, car model, sourcing country characteristics, bilateral friction, and probability of choosing i.

2.3 Sourcing decision

Car manufactures choose the optimal part supplier who offers the lowest price of part from the set of countries where are capable of producing compatible input j for car model ω, denoted $\mathcal{L}_{j\omega}$. From the supplier's binding participation constraint, price of part is the sum of delivered unit cost and average fixed cost. Assuming fixed cost related to exporting F_{in} is the same across all sourcing countries i, the minimization of part price is equivalent to that of variable delivered cost. Therefore, the probability that $i \in \mathcal{L}_{j\omega}$ is selected is the probability which c_{inj} is minimized:

$$\begin{aligned} \text{Prob}(i = i^*_{nj\omega}) &= \text{Prob}(c_{inj} \leq c_{knj}, \forall k \in \mathcal{L}_{j\omega}) \\ &= \text{Prob}\left(\frac{\psi_j z_{ij}}{w_i \tau_{in} r_{in} d_{in}} \geq \frac{\psi_j z_{kj}}{w_k \tau_{kn} r_{kn} d_{kn}}\right) \end{aligned} \tag{10}$$

With Fréchet distribution of $\psi_j z_{ij}$, the probability of country i to provide part j for car ω in market n can be derived as

$$\mathbb{P}_{i|nj\omega} = \frac{\left(w_i \tau_{in} r_{in} d_{in}\right)^{-\mu}}{\Phi_{nj\omega}} \tag{11}$$

, where $\Phi_{nj\omega} \equiv \sum_{k\in\mathcal{L}_{j\omega}} (w_k \tau_{kn} r_{kn} d_{kn})^{-\mu}$. Different from the sourcing condition constructed in Head and Mayer (2016), the probability here has one more layer of car parts, and thus affecting subsequent results to involve the part-destination interaction term instead of the two separately.

2.4 Aggregation to country-level exports

Aggregating over the set of cars Ω_n that is available in market n, I can derive total export of car part j from sourcing country i to market n. First, by substituting equation (11) into (9) and then multiply using the conditional probability of i is the optimal sourcing location, the unconditional expected productivity-adjusted sales of car parts j for car model ω in n can be expressed as

$$\begin{aligned}\mathbb{E}[\psi_j x_{inj\omega}] &= \mathbb{E}[\psi_j x_{inj\omega} \mid i = i^*_{nj\omega}]\mathbb{P}_{i|nj\omega} \\ &= \kappa_1 A_{\omega n} \theta_{\omega n}^{\frac{\rho}{1-\rho}} \left(w_i \tau_{in} r_{in} d_{in}\right)^{-\frac{1}{1-\rho}+\frac{1}{1-\alpha}-\mu} \Phi_{nj\omega}^{\frac{1}{(1-\alpha)\mu}-1}\end{aligned} \tag{12}$$

Next, before integrating across a continuum set of car models ω, some parametric distribution assumptions are assumed without loss of generality. Car quality and productivity parameter, $A_{\omega n}$ and $\theta_{\omega n}$ respectively, both follow Pareto distribution with shape parameter η and ζ correspondingly. The lower bound of car quality and productivity are set through zero profit condition for firms since otherwise it will exit from the market. Specifically, by equating equation (6) to zero and substitute $\underline{A_{\omega n}\theta_{\omega n}^{\frac{\rho}{1-\rho}}}$ to (12) with shape parameters, I obtain the following gravity form of equation after summing across ω.

$$\begin{aligned}\mathbb{E}[\psi_j x_{inj}] &= \int_{\omega \in \Omega_n} \mathbb{E}[\psi_j x_{inj\omega}] \\ &= \kappa_2 \underbrace{\Omega_n F_n \Phi_{nj}^{\frac{1}{(1-\alpha)\mu}-1}}_{\text{destination-part}} \underbrace{w_i^{\frac{1}{1-\alpha}-\mu-1}}_{\text{supplier}} \underbrace{(\tau_{in} r_{in} d_{in})^{\frac{1}{1-\alpha}-\mu-1}}_{\text{bilateral access.}}\end{aligned} \tag{13}$$

, where $\kappa_2 \equiv \frac{\rho}{1-\rho}\Gamma\left(1-\frac{1}{(1-\alpha)\mu}\right)\Gamma\left(1+\frac{1}{\nu}\right)\frac{\eta}{\eta-1}\left(\frac{\zeta}{\zeta-1}\right)^{\frac{\rho}{1-\rho}} J$. I assume that $\Phi_{nj\omega}$ is same across all car model ω which essentially allowing a possibility of each country which is capable of producing compatible car part j being sourced by every car model, and thus simplify the term to Φ_{nj}. Restricting the set of potential parts production countries, $\mathcal{L}_{j\omega}$, to be the same across different car models is not a strong assumption taken technology spillover in the auto industry into consideration. The part suppliers' fixed cost occurred during part delivery is assumed to be same across sourcing country i because in a given market n, advertising costs or fees paid to an intermediary for parts buyer searching is likely to vary little across locations of upstream firms. In the case where there is still bilateral dependent delivery fixed cost, it would be highly correlated with the term, d_{in}, and therefore dropped in F_{in}. For example, communication cost between parts supplier and car assembler is entangled with distance.

The key result is that the magnitude of trade elasticity is $-\frac{1}{1-\alpha}+\mu+1$, which decreases with respect to elasticity of substitution across car parts and increases with homogeneity in productivity across locations where produce a particular compatible car part for a given model. If parts are not substitutable across each other in terms of quality, firms are more responsive facing cost change of a particular part because they can't mitigate the effect through adjusting other parts. Meanwhile, in the extreme case where every sourcing location has the same productivity, manufacturers' choice of importing from country i rather than $i^{'}$ depends solely upon trade cost besides w_i and therefore raises the trade elasticity of bilateral frictions. Note that the trade elasticity does not involve parameter ρ which governs degree of substitution at car-level. This is because heterogeneity in final car demand vanishes after aggregation across all car models, whereas in equation (12) shows that at individual car model level, trade elasticity of parts increases as elasticity of substitution among final cars rises.

In order to estimate trade elasticity without car parts' marginal productivity data, I have to convert the left-hand side variable in equation (13) to aggregate export value of part j from country i to n by dividing ψ_j and then multiplying with price p_{ij}. Therefore, a final equation from the model represents expected export,

$$\mathbb{E}[X_{inj}] = \mathbb{E}[p_{ij}x_{inj}] = \kappa_2 \underbrace{\Omega_n F_n \Phi_{nj}^{\frac{1}{(1-\alpha)\mu}-1}}_{\text{destination-part}} \underbrace{w_i^{\frac{1}{1-\alpha}-\mu-1} \frac{p_{ij}}{\psi_j}}_{\text{supplier-part}} \underbrace{(\tau_{in} r_{in} d_{in})^{\frac{1}{1-\alpha}-\mu-1}}_{\text{bilateral access.}} \tag{14}$$

Different from equation (13), the expected export of part j from country i to n involves not only destination-part interaction characteristic but also that for supplier-part. In this paper, I am not using this equation to identify α and μ separately due to lack of domestic consumption data which is essential to recover μ in sourcing probability (11). However, the equation is well-suited for estimating the trade elasticity for each friction. Once observed variables representing tariff, rules of origin restriction and non-price factors are introduced, we can apply this equation to compare the magnitude of effects.

3 Data and variables

3.1 Dataset on FTAs and Rules of Origins

Rules of origin is an inevitable component in free trade agreements. In this paper, I study a period from 2000 to 2014 and 21 FTAs which cover 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 FTAs are either still active in 2014 or once have been active during the targeted time period. Information on each specific FTA such as years of entry into force and deactivate, parties involved, relevant articles and annexes about RoO provisions is provided by WTO Regional Trade Agreement Database and member countries' government website. A full list of this FTAs is presented in Table 1, where we see that South Korea has engaged in the most number of trade agreements with rest of countries, followed by Mexico. Countries such as China, Japan and India do not form free trade relationship with many other countries in our dataset.

As mentioned in the introduction, 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, cars, allows us to exploit this observable threshold instead of relying on other relatively subjective index. However, it also raises concern in terms of whether RVC is sufficient to represent the restrictiveness of rules of origin in general. RVC rules are normally used in combination with change of classification rules which require 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 50 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 region has to be at least 50% of the total net cost for a final car. Considering car parts which 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 same heading with final passenger car, the change of classification restriction is clearly not binding. What matters for the sourcing of car parts is entirely relying on the RVC rule. In general, the fact that change of classification rule is unbinding occurs for other FTAs as well. Therefore, RVC is a valid instrument for restrictiveness of RoO, at least in car sector.

However, there is still variation in the method of calculating regional value content across FTAs. There are three methods available, namely build-down, build-up and net cost method. 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 value of the good. The second is based on value of originating materials which RVC is the share of free trade region originated and self-produced materials in adjusted value of the good. Lastly, net cost based approach which is commonly used in automotive products replaces transaction value to net cost of a good and calculated RVC using the share net cost subtracted by value of non-originating materials out of total net cost. Most FTAs use 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.

Another concern will be as global value chain becomes increasingly fragmented, production of non-originating intermediates could involve the use of originating materials as inputs. This results in FTA region originated value to flow back home through intermediates imported from third countries. Nevertheless, calculation of regional value content ignores this additional layer along production chain. Value of non-originating materials thus include both originating intermediates further upstream and the "true" non-originating portion. Although fuzzy, failed to consider the entire production chain will not impose a threat to the validity of RVC given the share of domestic value-added which returns home through foreign intermediates only accounts for 1.5% of the total export on average as shown in Koopman et al. (2014).

Table 1: Description statistics on FTAs and RoO

	EIF Year	Car RVC (%)
pan-Euro-Mediterranean cumulation system / PEM Convention	1997	60
North American Free Trade Agreement (NAFTA)	1994	62.5[2]
EU - Mexico	2001	60
EFTA - Mexico	2002	40
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 - 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, Faroe Islands, Republic of Moldova, participants in the Barcelona Process and participants in the EU's Stabilization and Association Process. EFTA countries consist of **Iceland**, **Norway**, Switzerland, Liechtenstein during 2000-2014. NAFTA countries are the **U.S., Canada and Mexico**. Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, **Thailand**, and Vietnam form ASEAN. Countries in these organizations with bold highlighted as well as all countries in EU 28 are studied in this paper.

Table 1 shows that regional value content restriction imposed on cars varies from 35% to 65% with 77,939 out of 87,358 observations concentrated at 60% due to EU forms all FTAs with other countries at this level except South Korea. Later result will show that this could be problematic if

[2]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% since 2002.

we include both a FTA dummy and RVC variable in regression due to high collinearity.

3.2 Trade data

In order to estimate the gravity type equation derived in (14), we need bilateral export data for each HS6-digit car parts and final car as well as their Most Favored Nation (MFN) and preferential tariff. The source of these data is the World Integrated Trade Solution (WITS) and UN Comtrade. 26 HS6-digit categories are identified for car parts including engines, transmissions, brake system, steering and suspension components, electrical equipments, seats and other parts. Final car is restricted to passenger car only.

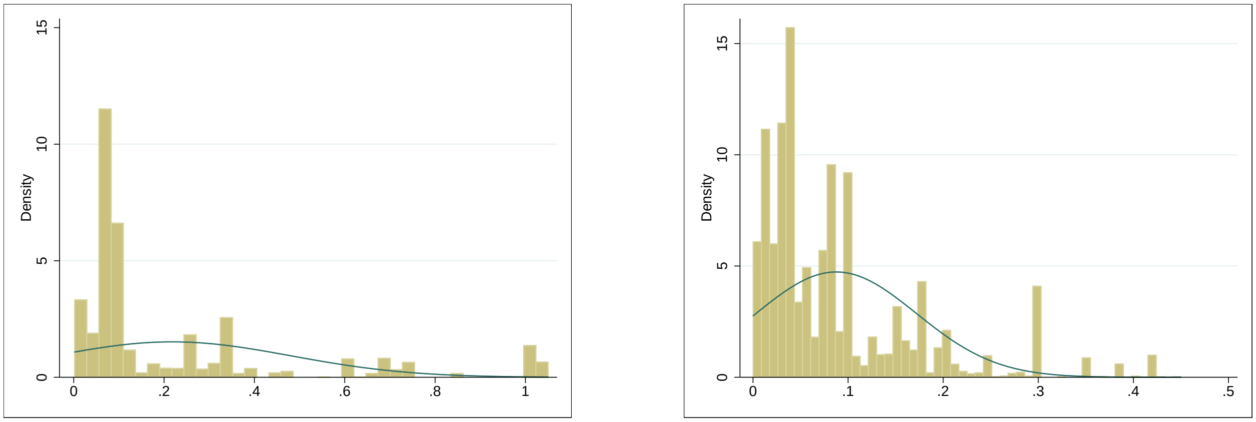
Figure 1 reports distributions of final car and car parts effectively applied tariff in panel (a) and (b) respectively. Effectively applied tariff would be MFN rate if a country pair does not form FTA and preferential tariff otherwise. There is also cases where tariff reduction after a FTA entered into force can be scheduled with a phase-out period, and effectively applied tariff reflects this gradual changes as well. Due to large number of country-pair-year observations concentrated at zero preferential tariff, Figure 1 excludes the zero-tariff pairs. As in panel (a), India has over 100% tariff on final cars, followed by China at around 86% before joining WTO but gradually lowering the tariff thereafter. Thailand has cars MFN tariff as high as 74%, while that for Brazil and Mexico is around 30% to 45%. Countries such as the U.S. and Canada has low tariff 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 a lower tariff compared to what imposes on final cars due to the nature of intermediate goods. China has relatively high tariff at 45% on car parts before entering WTO and decreases it to around 10% until 2014. Thailand and India are at the top tier of countries which impose high MFN tariff on car parts at 30% - 40%, followed by Brazil and Mexico around 20%. The parts tariff in U.S., Canada and Japan are approaching or at zero lower bound.

Although there is some dispersion in applied tariff rate on cars across countries, Figure 2 shows that preferential margin which is defined as the difference between MFN and preferential tariff is highly concentrated at 10%. The reason is that most MFN tariff is at around 10% as demonstrated in Figure 1, panel (a)[4]. There are still some countries such as India, Mexico and small European economies reducing car tariff substantially after forming FTA, which are located at the thin right tail, and correspond to them being the countries which have high applied tariff in certain years as presented in Figure 1. As what happens to RVC being concentrated at 60%, coefficient may fail to be identified when the variance of preferential margin is small.

[3]Exclude zero tariff.

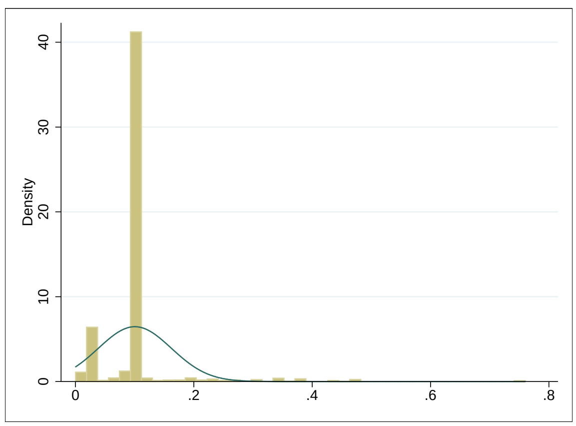
[4]The reason Figure 1, panel (a) and Figure 2 are not exactly the same is because phase-out tariff schedule is included in the former but not the latter. The difference between MFN and each year's phase-out tariff is included in plotting Figure 2.

Figure 1: Distribution of effectively applied tariff[3]



(a) Passenger cars (b) Car parts

Figure 2: Distribution of preferential margin on passenger car

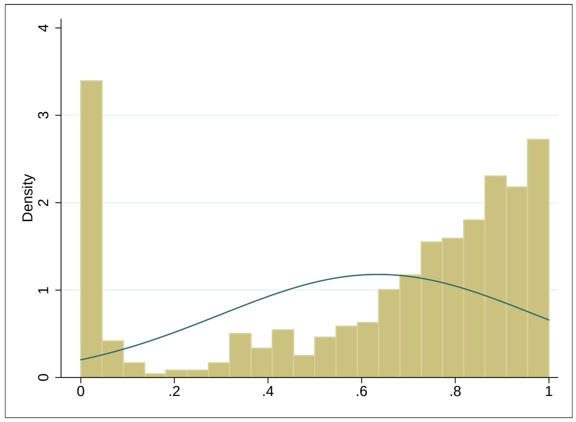


As this paper is also going to explore how the share of car export to FTA members affect car parts sourcing decision through the channel of rules of origin, car export and production data are essential. The latter is provided by the International Organization of Motor Vehicle Manufacturers (OICA) in unit of passenger cars produced each year for every country. I therefore match the export quantity data given by WITS with production to calculate the proportion of cars a country exports to its FTA partners in the total number of cars it produces in a given year. Figure 3 shows an alternative ratio of car export to FTA members versus total car export[5]. China, India, Thailand and Japan who are around zero share has fewer trade agreements signed with the rest of countries in the dataset, whereas they are major car exporters across the world. On the contrary, Mexico and some small European countries have share at one due to high dependency on NAFTA region

[5]Export ratio denominated with total export is actually what used in the regression presented in Table 4 instead of the one denominated with total production. The export to production ratio gives me unexpected estimation results, but I still want to use the production data in some way. So I leave this description of production data here for future modify.

and the EU. What at the mean are U.S. and Germany which 60% of their car exports flow to FTA member states.

Figure 3: Distribution of export share within FTA

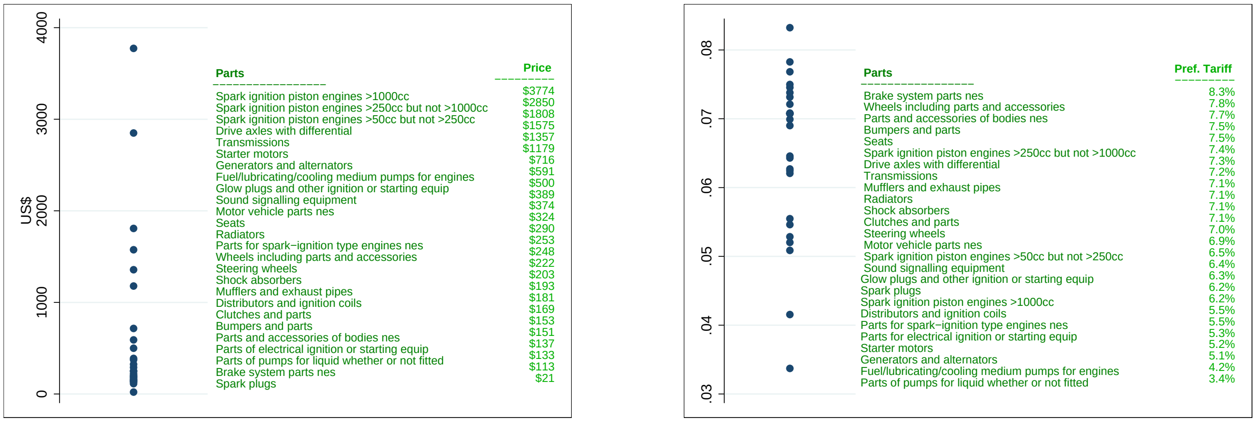


As 26 major car parts are identified and estimation is performed at product level, a natural question is whether the effect for rules of origin is homogeneous across different parts. Thus, I include parts characteristic, namely unit price from U.S. Census Bureau Trade Online. The unit price is the average price paid per unit of HS6-digit part by averaging unit value of their matched HS10-digit goods. The unit value data in U.S. Census is calculated using the sum of total value of the goods U.S. exports and total value of U.S. general imports in U.S. dollars divided by the physical volume of exports and imports based on the primary quantity measurement measured at HS10 digit only. Quantity of goods are chosen to be denoted solely in unit for harmonizing across different HS10-digit goods and aggregating to HS6-digit level. Variation in unit value of parts is demonstrated to be little across different sourcing countries and years, which explains why it's valid to use the world average price of parts instead of allowing the price to be differentiated by additional dimensions without scarifying much information.

Figure 4 panel (a) shows that engine is the most expensive part in a car, followed by transmissions and starter motors. Brake system and spark plugs[6] on the other hand are the least costly parts in producing a final car. Most parts cost \$100 to \$300 with prices start to be dispersed above \$1000. Instead of showing a representative part's applied tariff across country-year in Figure 1, panel (b) in Figure 4 is a graph of tariff across different parts averaging by all countries. Although parts' average tariff distributed from 3% to around 8%, they are relatively similar to each other considering a 0 to 50% scale in Figure 1. The fact that car parts tariff varies more in country-pair rather than product dimension substantiates the practice of transforming τ_{inj} to τ_{in} in section 2.2.

[6]Price for spark plugs are denoted at 6 units to fit a common car's usage.
[7]Average applied tariff exclude zero preferential tariff observations.

Figure 4: Heterogeneity in car parts



(a) Unit price (b) Applied tariff[7]

3.3 Other data on bilateral accessibility

Besides data on FTAs, trade and tariff, the standard explanatory variables used in gravity equations: distance, contiguity, and common language, are included to represent non-price factors that could shift delivery cost of car parts. These variables have been shown in past literature to matter for trade flows. Specifically, distance refers to the average number of kilometers on great-circle route between the main cities in a country pair. Contiguity and common language is whether countries share a land border or official language. As another important form of regional trade agreement, custom union (CU), unlike FTA, has no rules of origin governed since goods are freely circulated within CU. As 28 out of 40 in my dataset are EU countries, I therefore include custom union dummy to avoid omitted variable bias. Table 2 summaries the number of observations for each member type and EU pairs are nontrivial in our dataset.

4 Results

The goal of my analysis here is to testify whether rules of origin cause trade diversion in intermediate goods from non-FTA members to member states by focusing on car parts in particular. Equation (14) describing product trade flow across countries is transformed to an estimable way. With time dimension added, destination-part and supplier-part characteristics are replaced by fixed effects FE_{njt} and FE_{ijt} respectively. Bilateral frictions τ_{injt}, r_{int} and d_{in} are represented using observables:

$$\tau_{injt} = 1 + t_{injt}, r_{int} = \exp(\mathbf{R}'_{\mathbf{int}}\tilde{\beta}), d_{in} = \exp(\mathbf{D}'_{\mathbf{in}}\tilde{\delta}) \tag{15}$$

, where $\tilde{\beta}$, $\tilde{\delta}$ are vectors of the original trade cost parameters.

Table 2: Number of observations in each group

Relationship	Freq
neither	154,015
CU	141,436
RoO	87,358
Total	382,809

CU here is referred to European Union in particular. "Neither" is two countries do not form any RTA after 2000, whereas"RoO" means they have a FTA once signed with RoO terms during the sample period. Observations are in country pair-product-year level.

t_{injt} is the preferential tariff of car part j exported from sourcing country i to destination n. $\mathbf{R_{int}}$ is a vector identifies rules of origin status between countries i and n, including a CU dummy, a FTA dummy and its interaction with RVC variable. Lastly, the vector $\mathbf{D_{in}}$ is constructed using the standard gravity variable, distance, contiguity, and common language as defined in section 3.3.

By taking logarithm on both side of equation (14) and combine with (15), my benchmark regression is

$$\ln(X_{injt}) = \gamma \ln(1 + t_{injt}) + \mathbf{R'_{int}}\beta + \mathbf{D'_{in}}\delta + \text{FE}_{njt} + \text{FE}_{ijt} + \epsilon_{injt} \quad (16)$$

, where $\gamma = \frac{1}{1-\alpha} - \mu - 1$, $\beta = \gamma\tilde{\beta}$ and $\delta = \gamma\tilde{\delta}$. Table 3 reports our main results by adding variables of interest sequentially. Distance between the sourcing country and destination market consistently reduces car parts' export throughout six columns, whereas sharing the same border raises bilateral export significantly. Having the common official language, however, fails to have a significant effect on export for any forms of regression in the table. Column (2) to (6) build on (1) by including rules of origin and tariff costs besides non-price frictions. The coefficient on logarithm of one plus the part tariff rate estimates γ in equation (16), which is a composite parameter consisting elasticity of substitution across car parts (α) and degree of homogeneity in productivity across location-part (μ). Interestingly, only when I include product fixed effect separately with importer-year and exporter-year, is γ significantly different from zero and given an estimate of -1.85. The reason could be the variation of tariff across different sourcing countries when fixing destination, part and year is as small as 0.01 and reduces substantially compared to the case where allowing car parts to vary. Specifically, on one hand, for sourcing countries which have signed free trade agreement with destination market, they all face zero preferential tariff ignoring phase-out schedule. On the other hand, for sourcing countries which have not formed FTAs with destination market, they all take MFN tariff. After controlling for CU and FTA using dummy variables, the majority of variation across sourcing countries in this tariff term vanishes but those that experience tariff phase-out. Therefore, the effect of parts tariff is almost completely absorbed by the trade relationship dummies and fixed effect.

Table 3: Baseline results

Dep. Var	$\ln\left(\text{parts export}_{injt}\right)$					
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln \text{dist}_{in}$	-1.161***	-1.081***	-1.077***	-1.065***	-0.967***	-1.065***
	(0.135)	(0.130)	(0.129)	(0.126)	(0.134)	(0.140)
contig_{in}	0.697***	0.725***	0.717***	0.676***	0.703***	0.676***
	(0.174)	(0.163)	(0.163)	(0.163)	(0.169)	(0.181)
language_{in}	0.213	0.209	0.208	0.209	0.207	0.209
	(0.166)	(0.166)	(0.167)	(0.169)	(0.158)	(0.200)
CU_{int}	0.743***	1.256***	1.333***	1.149***	1.098***	1.149***
	(0.178)	(0.261)	(0.271)	(0.275)	(0.260)	(0.303)
$\ln\left(1+\text{parts tariff}_{injt}\right)$		4.402	4.554	4.600	-1.848*	4.600
		(3.233)	(3.273)	(3.099)	(0.915)	(2.996)
FTA_{int}		0.713***	-1.160	2.212***	2.192***	2.212***
		(0.227)	(1.344)	(0.315)	(0.331)	(0.173)
$\text{FTA}_{int} \times \text{RVC}_{int}$			3.251			
			(2.303)			
$\text{FTA}_{int} \times 1(\text{RVC}_{int} < 60\%)$				-1.772***	-1.857***	-1.772***
				(0.368)	(0.399)	(0.338)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} = 60\%)$				-1.617***	-1.719***	-1.617***
				(0.257)	(0.267)	(0.120)
Observations	382,388	380,607	380,607	380,607	381,029	380,607
R-squared	0.712	0.714	0.714	0.715	0.615	0.715
Importer & parts & year njt FE	✓	✓	✓	✓		✓
Exporter & parts & year ijt FE	✓	✓	✓	✓		✓
Importer & year nt FE					✓	
Exporter & year it FE					✓	
Parts j FE					✓	
S.E. cluster	n	n	n	n	n	n, i, j

The parts are defined at HS 6-digit level and their export in US dollar current value. It includes bilateral pairs for which auto parts exports were positive from 2000 to 2014. The omitted comparison group of RVC in column (4) to (6) is when it's greater than 60%. "Importer" and "exporter" refer to auto parts but not final car. Robust standard errors in parenthesis. Significance levels: *: 10%, **: 5%, ***: 1%.

As our target of interest, the coefficients of CU, FTA and its interactions constitute β. Bilateral export value in a given year and product tripled after exponentiating the coefficient for two countries that share the same custom union. In column (2), the boost on parts export from forming a FTA is smaller than that of having a CU since the latter is a deeper form of integration. After interacting FTA dummy with RVC as a continuous variable, both its level and interaction term turn out to become insignificant. The reason, as mentioned in Table 1, is that about 90% of the observations having RVC at 60%, which leads to near perfect collinearity problem between these two variables. To resolve this issue, I replace the continuous RVC variable to a set of dummies that are divided using 60% as threshold, which essentially is similar to compare effects in different quantiles. As column (4) shows, when RVC is greater than 60%, the value of parts imported from FTA member countries is nine times[8] higher than those from third countries. Contrary to this high RVC scenario, intermediates trade promotion drops dramatically for groups that have RVC smaller or equal to 60% although remaining positive, in which parts sourced from FTA member states are less than doubled those from non-member. Furthermore, we see that the trade diversion of car parts is convex with respect to RVC changes, which means firms will adjust their sourcing allocation much mildly facing same amount of RVC increase when it is low because content rule does not impose enough power of restriction. Compared to the 1.85 elasticity of tariff change on trade flow that is imposed directly on intermediates, this indirect origin restriction on final good could lead to a even larger facilitation of intra-RTA intermediates trade. Therefore, these results indeed imply that the higher RVC on final goods is, the more trade diversion on intermediate goods from non-members to FTA member countries, and the effect is non-linear and non-negligible. Column (6) repeats the same setup as in (4) except multi-clustering the standard error in sourcing country, destination and product. All estimates are still robust.

As Table 3 shows rules of origin on final goods impede intermediate trade with non-member countries through setting regional value content requirement, Table 4 further decomposes the effect of RVC to three channels. Having column (6) as my preferred estimates in Table 3, I build on the FTA-RVC dummy by interacting it with three more variables, namely the share of car export RTA[9] members in total car export value of country n in year t, the weighted average preferential margin that country n faces when exporting to all RTA members in year t, and the log world average unit value of part j. The results partially testify my hypothesis with some data limitations. In column (1), when RVC is greater than 60%, firms are less flexible in sourcing location choice if RTA member countries are important final car export markets. One percent increase in car export share to RTA members will raise 1.7% change in parts sourced from a RTA member on average compared to non-members. However, when the value content rule is lower than or equal to 60%,

[8]The FTA level term picks up the effect of omitted group, RVC greater than 60%, so $\exp(2.12) \approx 9.13$.

[9]RTA including both FTA and CU members should be taken into consideration. One reason is that EU countries can only sign FTA with other countries jointly. The other reason is that goods are freely traded within EU without RoO bounded.

RVC may not have enough bite to significantly divert intermediates sourcing allocation even when in the extreme case where all final cars' exports are within RTA region. Moreover, it is unlikely that the 1.7% increase of part imported from RTA members is due to consumers' taste preference towards final car that consists of domestic parts, a concept introduced in Head and Mayer (2016). The reason is that the export share measurement here is a weighted average of all country n's RTA partners instead of the particular part's sourcing country i. Despite there could be high correlation of taste and part quality across all RTA members, the fact that there is no significant effect in low RVC groups rules out the possibility of this alternative explanation because otherwise the taste preference should constantly exist no matter what content rule country n has to comply.

Column (2) is testing the trade-off between tariff benefit and production cost. When regional value content is restricted at 60%, preferential margin could compensate the raising cost of production from not choosing the lowest part supplier as tariff reduction is larger. As a result, firms have incentive to comply with rules of origin and value of parts sourced from RTA member grows rapidly by 13.29% with preferential margin increases by one percent. The result, however, is reverted in the case where value content rule becomes tighter. Economically, it may be due to RVC is so high that firms become RoO defier and sacrifice taking lower tariff. It could motivate firms to actively search for lower cost supplier and enlarge the set $\mathcal{L}_{j\omega}$ in order to offset the forgone tariff benefit. Therefore, as tariff reduces more in a trade agreement with high RVC, RoO complier will source more parts from RTA members, whereas RoO defier will be incentivized to source even more parts from third countries. The latter seems to dominate the former in column (2) when not many controls are added, but offset each other in column (4) when all variables are included. When RVC is lower than 60%, the constraint is not binding as similar to column (1). Notice that parts tariff here has positive and weakly significant effect on trade flow which is counterintuitive. A potential reason is multicollinearity concern brought through preferential margin on cars as shown in Figure (2). This problem weakens the validity of estimates in column (2).

In terms of car part's unit price, coefficients are not significant indicating there is not a systematic pattern in selecting sourcing location across inputs. On one hand, expensive parts might be easier to break rules of origin and should source within RTA region. On the other hand, firms in country n might enjoy a discount or cost advantage in sourcing expensive parts from non-member countries which is harder for them to switch supplier. If then, they will substitute many cheaper parts to RTA supplier. The mixed effect, therefore, is ambiguous.

The last column in Table 4 combines all three channels. Each set of interactions provide consistent results with including them separately except a change of magnitude. In addition, as modifiers to the main FTA and RVC effects, FTA and FTA-RVC interaction fail to sustain significant coefficients although the signs are still as expected.

Table 4: Heterogeneous effects through RoO

Dep. Var	$\ln\left(\text{parts export}_{injt}\right)$			
	(1)	(2)	(3)	(4)
$\ln \text{dist}_{in}$	-1.062***	-1.043***	-1.065***	-1.041***
	(0.145)	(0.154)	(0.142)	(0.177)
contig_{in}	0.682***	0.694***	0.676***	0.698***
	(0.188)	(0.171)	(0.172)	(0.180)
language_{in}	0.210	0.224	0.209	0.222
	(0.204)	(0.201)	(0.199)	(0.228)
CU_{int}	1.142***	1.196***	1.149***	1.186***
	(0.306)	(0.306)	(0.304)	(0.309)
$\ln\left(1+\text{parts tariff}_{injt}\right)$	4.752	4.807*	4.603	4.765
	(2.927)	(2.814)	(2.995)	(2.849)
FTA_{int}	1.010***	2.432***	2.971**	1.015
	(0.168)	(0.716)	(1.184)	(1.264)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} < 60\%)$	-0.356	-1.965**	-2.501**	-0.295
	(0.256)	(0.870)	(1.043)	(1.141)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} = 60\%)$	-0.592**	-2.985***	-2.389**	-1.885
	(0.251)	(0.562)	(1.101)	(1.197)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} < 60\%) \times \text{expsh}_{nt}^{\text{RTA}}$	-0.423			-0.462
	(0.371)			(0.398)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} = 60\%) \times \text{expsh}_{nt}^{\text{RTA}}$	0.222			0.312
	(0.288)			(0.244)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} > 60\%) \times \text{expsh}_{nt}^{\text{RTA}}$	1.710***			2.149***
	(0.360)			(0.204)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} < 60\%) \times \Delta\text{tariff}_{nt}^{\text{RTA}}$		-0.439		0.304
		(4.702)		(4.006)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} = 60\%) \times \Delta\text{tariff}_{nt}^{\text{RTA}}$		13.29***		13.79***
		(4.426)		(4.653)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} > 60\%) \times \Delta\text{tariff}_{nt}^{\text{RTA}}$		-5.853*		4.618
		(3.023)		(4.335)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} < 60\%) \times \ln(\text{unit value}_j)$			-0.00466	-0.00992
			(0.0748)	(0.0894)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} = 60\%) \times \ln(\text{unit value}_j)$			0.00231	0.00380
			(0.0424)	(0.0413)
$\text{FTA}_{int} \times 1(\text{RVC}_{int} > 60\%) \times \ln(\text{unit value}_j)$			-0.123	-0.129
			(0.215)	(0.225)
Observations	380,607	380,607	380,607	380,607
R-squared	0.715	0.715	0.715	0.715

All regressions include importer-parts-year njt and exporter-parts-year ijt fixed effects. $\text{expsh}_{nt}^{\text{RTA}}$ is the share of car export to RTA members (including both FTA and CU) in total country n's export value of car in year t. $\Delta\text{tariff}_{nt}^{\text{RTA}} = \ln(1+\text{MFN tariff}_{nt}^{\text{RTA}}) - \ln(1+\text{pref tariff}_{nt}^{\text{RTA}})$ is the preferential margin on final cars country n face when exporting to all its RTA member states in year t. Car MFN and preferential tariff are average of each RTA country weighted by n's car export share to each country. Unit value of part j is derived as described in section 3.2. Variation across time and sourcing country in unit value of parts is not necessary and ignored here. Standard error is in parenthesis and multi-clustered in n, i, j. Significance levels: *: 10%, **: 5%, ***: 1%.

5 Conclusion

This paper empirically estimates the distortive effect of rules of origin on intermediate goods trade by exploring a particular dimension of sourcing restrictions, regional value content. It further investigates on 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 intermediate goods. A clear takeaway from results by applying the framework to car industry is that car manufacturers do redistribute their parts suppliers when facing a more restrictive and binding regional value content rule. When RVC is above 60%, RTA effect is 2.2, which almost fourfold that in Cipollina and Salvatici (2010) and Head et al. (2013). The intermediates trade promotion effect, however, is not linear with respect to RVC, but convex. RTA effect declines to 0.44 when RVC is low. Therefore, the expected RTA effect in the entire sample is similar but slightly higher than 0.59, the estimate from past literature. In comparison, one percent direct tariff reduction on parts boosts the intra-RTA parts trade by 1.8%.

Going beyond the main effect of regional value content rule, it implicitly imposes heterogeneous bounds to different groups of firms. Final car exporters who target RTA markets find high RVC matters rather than those that focus on other markets or domestic firms. Among firms which export final car to RTA member countries, they additionally face the decision of whether to comply with RoO or deny it depending on the tariff benefit and production cost saving whichever is higher. When the former is more attractive, firms choose to reallocate inputs towards RTA region; while too high the RVC rule will deter firms from doing so because the increase of production cost outweigh preferential treatment. Intending to identify which type of car parts firms will reallocate, I find the selection is actually ambiguous.

Theoretically, this paper shows a three-layer model: consumers, downstream firm, and upstream supplier. It combines the CES structure of both consumers and market with heterogeneous firm product and firms' sourcing decision. This framework can be applied to reduced form estimation because it delivers a handy gravity form of equation, as well as structural estimation of parameters for counterfactual analysis as what is performed in Head and Mayer (2016). Due to data limitation, I am unable to estimate structurally, nor have I done counterfactual practice on policies. In model itself, I simplify rules of origin to an *ad-valorem* variable without attempting to develop a full-fleshed model with intermediate inputs selection and export activities by downstream firms. The model can potentially be extended to five parties: headquarter, intermediate inputs supplier, assembler, domestic consumers and foreign buyers. These and other aspects of global production chain provide a full agenda for future research.

Despite having limitations, this paper contributes to the current 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 and clarifying the audience of a specific policy. Too low a RVC will not function as ensuring the origin of goods, while too high of it will either ruin market efficiency or cause low utilization rate of the trade agreement. This paper serves as a pioneer exploration of the optimal RVC by using 60% as cutoff, while leaving future work to build upon.

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Appendix

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:

$$x_{inj\omega} = \left\{ A_{\omega n}^{1-\rho} \theta_{\omega n}^{\rho} \rho \left[\int_{j \in J} (\psi_j x_{inj\omega})^{\alpha} dj \right]^{\frac{\rho}{\alpha}-1} \frac{\psi_j^{\alpha}}{c_{inj}} \right\}^{\frac{1}{1-\alpha}}. \tag{A-1}$$

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

$$Z_{in\omega} = \int_{j \in J} \psi_j^{\alpha} \left(A_{\omega n}^{1-\rho} \theta_{\omega n}^{\rho} \rho Z_{in\omega}^{\frac{\rho}{\alpha}-1} \frac{\psi_j^{\alpha}}{c_{inj}} \right)^{\frac{\alpha}{1-\alpha}} dj.$$

Solving this equation, it's straightforward to verify

$$Z_{in\omega} = \rho^{\frac{\alpha}{1-\rho}} A_{\omega n}^{\alpha} \theta_{\omega n}^{\frac{\alpha\rho}{1-\rho}} \left[\int_{j \in J} \left(\frac{\psi_j}{c_{inj}} \right)^{\frac{\alpha}{1-\alpha}} dj \right]^{\frac{1-\alpha}{1-\rho}}. \tag{A-2}$$

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