

**MODELING CHANGES IN
PREFERENTIAL RULES OF ORIGIN**

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ABSTRACT

We develop an industry-specific economic model of changes in trade flows, prices, and the location of production that could result from a revision of the regional content requirements of a free trade agreement. We illustrate how certain partial equilibrium assumptions can significantly reduce the data requirements of the model. We report a series of model simulations. In the model, the effects on the regional content of production and prices their consumers face are determined by supply chain configurations under the original rules of origin and the costs of production in alternate supply chains, but only for firms that combine production within and outside of the region under the original rules of origin.

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1. Introduction

Rules of origin (ROO) define the country of origin of a product that is traded across borders, and they determine eligibility for preferential tariff rates under a free trade agreement (FTA).¹ ROO are industry-specific, and they can be complex for goods that combine stages of production that are located in different countries. The chemical, apparel and textiles, and automobile industries have especially complex rules in U.S. trade agreements.² The ROO can shape the multinational sourcing decisions of firms, and compliance with these rules can create administrative burdens, for example if the rules require tracing the origin of inputs supplied by subcontractors.³

It is difficult to predict the economic effects of a change in preferential ROO. For example, an increase in the regional content requirements for preferential tariff treatment can lead to an increase or decrease in the regional content of production, because firms are not required to comply: it may be more cost-effective for the firms to source their inputs from countries outside of the FTA region and forego preferential tariff treatment. Another reason that it is difficult to model the effects of changes in regional content requirements is that these rules apply at the firm level, to narrowly defined products.

Despite these challenges, this paper develops an industry-specific partial equilibrium model of changes in trade flows, prices, and the location of production that could result from a revision of the regional content requirements of a free trade agreement. Partial equilibrium modeling is arguably the most appropriate analytical framework for predicting the economic effects of changes in ROO. Computable general equilibrium (CGE) models are commonly used to estimate the economy-wide effects of changes in trade policies, but it is difficult to analyze changes to the ROO using a CGE model.⁴ The sectors in CGE models are typically too aggregated, since rules apply to specific product lines. In addition, the rules apply separately to the sourcing of each firm, not industry-

¹ Inama (2009), Congressional Research Service (2015) and United States International Trade Commission (2016) provide background information about rules of origin.

² United States International Trade Commission (2016, 2017) discuss the rules of origin for each of these industries in past U.S. trade agreements.

³ Congressional Research Service (2015) echoes concerns that ROO can be “complex, sometimes subjective, and time-consuming” in practice.

⁴ U.S. International Trade Commission (2003) modeled the effects of textile and apparel ROO in the United States-Singapore Free Trade Agreement. The CGE model discounted the scheduled reductions in U.S. tariff rates on imports of textiles and apparel by 50 percent and then by 100 percent to account for the restrictive ROO in the sector. This simple implementation suggests the effects of ROO, but it does not capture the details of the rules. Georges (2010) presents a CGE analysis that specifically focuses on ROO. His CGE model is calibrated to distortions in the baseline economy due to the ROO. Still Georges’ analysis is at the industry level and does not analyze responses of specific firms that are subject to the rules.

average sourcing, but CGE models typically do not track individual firms. Another approach to this issue is to analyze international input-output tables and estimates of trade in value added. These types of data are often cited in discussions of ROO, because they can provide valuable information about aggregate international sourcing patterns.⁵ However, the accounting relationships in these datasets are not a tool for predicting the effects of changes in ROO. They do not indicate how trade and production might adjust.

The data requirements of an economic model of changes in the ROO can be daunting, since the rules apply separately to each firm for each product line; however, we adopt certain partial equilibrium assumptions that reduce these data requirements by ruling out alternative supply chains that would not become more cost-efficient under the revised ROO. The model requires data on the number and market shares for firms with each supply chain configuration in the industry. It also requires data on the costs of alternative supply chains, but only for the firms that combine production within and outside of the FTA region under the initial ROO.

Rules of origin are typically elaborate legal provisions, while the representation of the rules in this paper is greatly simplified. In the model, each stage of production is clearly identified by the country in which it occurs, and there are no ambiguities about transformation or tariff classifications of the products. While this stylized representation of ROO, and specifically regional content requirements, is a limitation of the model, it allows us to focus on estimating the economic effects of the policy change within a tractable model with limited data requirements.

We report a series of model simulations that quantify changes in regional content and a market price index in response to a revision in the ROO that increases the regional content requirement for preferential tariff treatment. The simulations provide predictions about the direction of changes, under different scenarios, using illustrative data inputs and parameter values.⁶

The increase in regional content requirements increases the market price index in countries in the FTA region by increasing the costs in supply chains that meet the regional content requirements under the initial ROO but do not meet the content requirements under the revised ROO. The regional content of industry production increases if there are no changes in the location of

⁵ Flatness and Rasmussen (2017) is a recent example of this approach. The authors analyze data from the OECD's trade in value added dataset. They find that "the share of U.S.-produced content in manufactured imports from Mexico and Canada has eroded significantly since the mid-1990s," especially in the motor vehicles industry. This study is cited in policy debates over potential changes in the NAFTA rules of origin.

⁶ The model can also provide quantitative estimates of the economic effects if applied to actual industry data, though application to a specific industry is beyond the scope of this paper.

production and marginal costs of production are constant. Firms with some production outside of the region will face higher tariffs under the revised ROO, and they will pass this increase in marginal costs to consumers in higher prices. This will reduce the quantity of their sales.

On the other hand, if firms adjust their supply chains after the change in the ROO, then the regional content of industry production can increase, stay the same, or even decline depending on how the changes in the ROO affect the costs of alternative supply chains, and these cost-reducing adjustments offset part of the increase in market prices.

The rest of the paper is organized into five sections. Section 2 presents a model with three alternative supply chains. Section 3 reports model simulations. Section 4 concludes with a discussion of potential extensions to the modeling framework.

2. A Model with Three Alternative Supply Chains and One Market

Since regional content requirements apply to the products of individual firms, the model is a microeconomic analysis of production location and trade decisions. The model addresses the interactions of the firms as they compete. Also, to be relevant to industries with complex ROO, the model includes multiple stages of production that can be located in different countries, and includes a variety of firms that produce entirely within the FTA region, produce entirely outside of the region, or combine production within and outside of the region.

We assume that there are three countries. Countries a and b are within the FTA region, and country c is outside of the region. There are two production stages, an upstream production process and a downstream process. The intermediate good and downstream value-added are combined in fixed proportions with perfect substitution between national sources at each production stage. The model focuses on a single national consumer market, country a within the FTA region. We use the notation xy to indicate a supply chain in which the upstream product is sourced from country x and transformed into the downstream product in country y , and then the finished product is sold to consumers in country a . (It is straightforward to extend the model to include more countries and more stages of production, as we discuss in Section 4. The model is kept simple in this paper in order to more clearly illustrate several basic points about the economics of changes in the ROO. All of the supply chains that we consider end with consumption in country a , by assumption. We omit the destination country from the name of the supply chain to simplify the notation.)

A firm in the industry must incur a fixed cost to locate a stage of production in each country. This location-specific cost could include costs of investment in physical capital or costs of establishing a contractual relationship with local producers. We assume that these costs are large enough that each stage of production in a firm's supply chain is located in a single country. For some firms, the fixed costs are so different across the countries that the firms will never relocate in response to the change in the ROO, because the change in relative marginal production costs does not offset the difference in fixed costs. For other firms, the fixed costs are approximately the same across the countries, and the firms might relocate, because their location decisions are determined by differences in their marginal production costs rather than their fixed costs.⁷

The model assumes that there are three types of supply chains serving the market in country *a*. The three types are: firms with upstream and downstream production within the region in country *b* exported to country *a* within the region (supply chain *bb*); firms with upstream production outside of the region in country *c*, exported to be used in downstream production within the region in country *b* and then exported to country *a* within the region (supply chain *cb*); and firms with upstream and downstream production outside of the region in country *c*, with the final product exported to country *a* within the region (supply chain *cc*). There are N_{bb} firms serving country *a* through the *bb* supply chain under the initial ROO, N_{cc} firms with supply chain *cc*, and N_{cb} firms with supply chain *cb*. The three types of firms have different marginal costs associated with each of the supply chains. We assume that the firms' initial supply chains reveal useful information about their relative marginal costs of production, as we explain below.

To predict the economic effects of a change in the ROO, we also need to specify how the firms compete in the market. We assume that the firms produce differentiated products and are monopolistic competitors, as in a Dixit-Stiglitz-Krugman model of international trade, with total expenditure on the products of the industry equal to a constant share of aggregate expenditures in country *a* and with a constant elasticity of substitution σ among the unique varieties of the firms.⁸ Under these assumptions, each firm's price is a constant mark-up over its marginal costs.

⁷ The model does not require a specific measure of the fixed costs of production in each location, just a more general assessment about whether these fixed costs are approximately the same across countries (and therefore not a factor in location decisions) or different enough that they determine location.

⁸ Krugman (1980) and Helpman and Krugman (1985) are examples of Dixit-Stiglitz models of international trade. The constant expenditure share reflects an assumption that consumers have Cobb-Douglas preferences for the composite products of different industries, including the industry that is the focus of the model. This assumption also implies that the total demand for the products of the modeled industry has a price elasticity of negative one.

We assume that the initial rules of origin have a relatively low regional content requirement: they do not require that upstream production occurs within the FTA region for the final product to be eligible for the preferential tariff rate when it is imported into country a . In this case, we expect a firm to manufacture the finished product within the region (in country b) but source the upstream input from outside the region (in country c) if its cost of supply chain cb under the initial ROO is lower than its cost of sourcing entirely within the region through supply chain bb or entirely outside of the region through supply chain cc .

On the other hand, we assume that the revised rules include a higher regional content requirement for the final product to be eligible for preferential tariff treatment when it is imported into country a . Specifically, we assume that both stages of production need to be located within the FTA region (in country b). In this case, we expect a firm with a cb or cc supply chain to switch to sourcing all of its inputs within the region (locating all production in country b) if its cost of supply chain bb is less than its cost of supply chain cb or cc , *including the tariff*, under the revised ROO.

We adopt the partial equilibrium assumption that the costs of production (i.e., the cost of supply before the tariff of each stage) in each location are exogenous and are not affected by the change in the ROO. In this case, the change in the ROO increases the marginal costs of supply chain cb by exactly the amount of the tariff. The cost of supply chain cb rises absolutely also relative to the costs of supply chains bb and cc , which do not change with the revision to the ROO. We also adopt the partial equilibrium assumption that aggregate expenditure in country a is exogenous.

Table 1 lists the marginal production costs for each type of firm (defined by the firm's initial supply chain) for each alternative supply chain. The notation $M_{z \rightarrow xy}$ represents the marginal production costs of a type z firm that adopts an xy supply chain.

Table 1: Marginal Costs for Each Supply Chain, Including the Tariff

Initial Supply Chain and Firm Type	Alternative Supply Chain	Marginal Costs under the Initial ROO	Marginal Costs under the Revised ROO
<i>bb</i>	<i>bb</i>	$M_{bb \rightarrow bb}$	$M_{bb \rightarrow bb}$
<i>cb</i>	<i>bb</i>	$M_{cb \rightarrow bb}$	$M_{cb \rightarrow bb}$
<i>cc</i>	<i>bb</i>	$M_{cc \rightarrow bb}$	$M_{cc \rightarrow bb}$
<i>bb</i>	<i>cb</i>	$M_{bb \rightarrow cb}$	$\tau M_{bb \rightarrow cb}$
<i>cb</i>	<i>cb</i>	$M_{cb \rightarrow cb}$	$\tau M_{cb \rightarrow cb}$
<i>cc</i>	<i>cb</i>	$M_{cc \rightarrow cb}$	$\tau M_{cc \rightarrow cb}$
<i>bb</i>	<i>cc</i>	$\tau M_{bb \rightarrow cc}$	$\tau M_{bb \rightarrow cc}$
<i>cb</i>	<i>cc</i>	$\tau M_{cb \rightarrow cc}$	$\tau M_{cb \rightarrow cc}$
<i>cc</i>	<i>cc</i>	$\tau M_{cc \rightarrow cc}$	$\tau M_{cc \rightarrow cc}$

The variable τ represents the power of the non-preferential tariff on final products that are imported into country *a*. It is equal to one plus the tariff rate if the imports are not eligible for preferential tariff treatment and is equal to one otherwise. The change in the ROO increases the marginal cost of the *cb* supply chain only.

First, we use the model to analyze how the changes in the ROO affect the overall regional content of the imports of country *a*. Equation (1) represents their regional content under the initial ROO. This measure is the ratio of the pre-tariff value of upstream and downstream production located in country *b* (within the region) to the total pre-tariff value of production in all three supply chains in all countries.⁹

$$(1) \quad RC_a = \frac{N_{bb} q_{bb \rightarrow bb} \left(\frac{\sigma}{\sigma-1}\right) M_{bb \rightarrow bb} + N_{cb} q_{cb \rightarrow cb} \left(\frac{\sigma}{\sigma-1}\right) M_{cb \rightarrow cb} D_{cb}}{N_{bb} q_{bb \rightarrow bb} \left(\frac{\sigma}{\sigma-1}\right) M_{bb \rightarrow bb} + N_{cb} q_{cb \rightarrow cb} \left(\frac{\sigma}{\sigma-1}\right) M_{cb \rightarrow cb} + N_{cc} q_{cc \rightarrow cc} \left(\frac{\sigma}{\sigma-1}\right) M_{cc \rightarrow cc}}$$

The variable $q_{z \rightarrow xy}$ represents the volume of the final product from type *z* firms using supply chain *xy*, and the variable D_{cb} represents the ratio of the value added in downstream production in country *b* to the total value of the product from the *cb* supply chain. The parameter σ is the

⁹ This equation is simplified because we have assumed that there are only three types of supply chains. If there were also a *bc* supply chain, for example, it would also affect regional content, we would add a term to both the numerator and denominator of equation (1).

elasticity of substitution among the varieties of the firms. The term $N_{bb} q_{bb \rightarrow bb} \left(\frac{\sigma}{\sigma-1} \right) M_{bb \rightarrow bb}$ is the value of production from supply chain bb that is ultimately consumed in country a . Equation (2) restates the regional content measure in terms of expenditure shares of the different supply chains, the tariff rate, and the downstream marginal production costs of cb firms in their initial supply chain.¹⁰

$$(2) \quad RC_a = \frac{S_{bb} + S_{cb}(D_{cb})}{S_{bb} + S_{cb} + S_{cc} \left(\frac{1}{\tau} \right)}$$

The variable S_{xy} represents the share of expenditures in country a on the products from the xy supply chain under the initial ROO.

Equation (3) is the overall regional content after the change in ROO if none of the firms relocates production. This would be the case if the fixed cost of producing in the different countries were large enough to offset the potential reduction in marginal costs. Again, the measure of regional content only requires share information, the tariff rate, and the downstream production costs of cb firms in their initial supply chain.¹¹

$$(3) \quad RC_a = \frac{S_{bb} + S_{cb}(D_{cb})(\tau)^{-\sigma}}{S_{bb} + S_{cb}(\tau)^{-\sigma} + S_{cc} \left(\frac{1}{\tau} \right)}$$

In this case without relocation, overall regional content remains the same or increases with the change in the ROO under the partial equilibrium assumption. Firms with cb supply chains face higher tariffs, which they pass onto consumers in higher prices, and this reduces the relative demand for their product. The higher tariffs also increase the market price index, but the resulting changes in the numerator and denominator of the ratio in equation (3) offset each other.

More generally, regional content changes to reflect changes to location decisions. We assume that a share δ of firms in the cb supply chain have approximately the same fixed costs across the countries and will shift to another supply chain if it has a marginal cost advantage under the revised ROO, while the rest of the cb firms have fixed costs that are so different across countries that they will not relocate in response to the change in the ROO.

Firms with a cb supply chain under the initial ROO have revealed that this supply chain is less costly

¹⁰ Importantly, this calculation does not require cost data for most of the cells in Table 1. We explicitly derive equation (2), and related equations (3), (11), and (12) in the Technical Appendix.

¹¹ We assume that the number of firms in each type are exogenous to the model, determined by worldwide exit decisions of these global firms that are not significantly affected by the change in the ROO.

for them than *cc* or *bb* under the initial ROO. For the share δ of these firms that have approximately the same fixed costs in the different supply chains, their marginal production cost in the *cb* supply chain is also lower under the revised ROO.

$$(4) \quad M_{cb \rightarrow cb} < \min [M_{cb \rightarrow bb}, \tau M_{cb \rightarrow cc}]$$

Under the revised ROO, these firms' sourcing decisions depend on the size of the tariff on final goods and on their relative marginal production costs in the alternative locations. These firms will shift to a *bb* supply chain under the revised ROO if:

$$(5) \quad M_{cb \rightarrow bb} < \min [\tau M_{cb \rightarrow cb}, \tau M_{cb \rightarrow cc}]$$

On the other hand, they will shift to supply chain *cc* under the revised ROO if:

$$(6) \quad \tau M_{cb \rightarrow cc} < \min [\tau M_{cb \rightarrow cb}, M_{cb \rightarrow bb}]$$

In this last case, the firm switches to a supply chain with less regional content in response to the increase in the regional content requirement, because it will be less costly for them to forego the tariff preferences than to comply with the revised ROO.

If neither of the inequalities in (5) and (6) holds, then the firms will continue with their *cb* supply chains under the revised ROO, as will the share $1 - \delta$ of the *cb* firms for which the *cb* supply chain has a significant fixed cost advantage.

Increasing the regional content requirements only affects the sourcing of the *cb* firms, because they are the only firms with a combination of upstream production outside of the region and downstream production within the region under the initial ROO. Firms with a *bb* supply chain under the initial ROO have revealed that this supply chain is less costly than *cb* or *cc* supply chains under the original ROO. For the share of these firms that have approximately the same fixed costs in the different supply chains, their marginal production cost in the *bb* supply chain is revealed to be lower under the initial ROO.

$$(7) \quad M_{bb \rightarrow bb} < \min [M_{bb \rightarrow cb}, \tau M_{bb \rightarrow cc}]$$

Its cost within the region will be the same under the revised ROO, since the revision to the ROO only raises the costs of supply chains that include some production outside of the region. These *bb* firms will have no incentive to relocate production in response to the change in the ROO.¹² None of these

¹² For these firms, the revealed cost advantage of production within the region under the original ROO

firms will shift to supply chains *cb* or *cc* because supply chain *bb* will remain the lowest cost alternative under the revised ROO, since (7) implies (8).

$$(8) \quad M_{bb \rightarrow bb} < \min [\tau M_{bb \rightarrow cb}, \tau M_{bb \rightarrow cc}]$$

In addition, the share of the *bb* firms for which the *bb* supply chain has a significant fixed cost advantage also will no change their supply chain.

Finally, firms with a *cc* supply chain under the initial ROO have revealed that this supply chain is less costly than *cb* or *bb* supply chains under the original ROO. For the share of these firms that have approximately the same fixed costs in the different supply chains, their marginal production cost in the *cc* supply chain is revealed to be lower under the initial ROO.

$$(9) \quad \tau M_{cc \rightarrow cc} < \min [M_{cc \rightarrow cb}, M_{cc \rightarrow bb}]$$

Again, none of these firms will shift to supply chains *cb* or *bb*. Supply chain *cc* will remain the lowest cost alternative under the revised ROO, since (9) implies (10).

$$(10) \quad \tau M_{cc \rightarrow cc} < \min [\tau M_{cc \rightarrow cb}, M_{cc \rightarrow bb}]$$

The share *cc* firms for which the *cc* supply chain has a significant fixed cost advantage will also not change their supply chain. Equation (11) is the regional content of the imports of country *a* if the inequality in (5) holds and *cb* firms shift to supply chain *bb*, moving all of their production into the FTA region.

$$(11) \quad RC_a = \frac{S_{bb} + S_{cb}(1-\delta) (\tau)^{-\sigma} (D_{cb}) + S_{cb} \delta (R_{bb})^{-\sigma}}{S_{bb} + S_{cb} (1-\delta) (\tau)^{-\sigma} + S_{cb} \delta (R_{bb})^{-\sigma} + S_{cc} \left(\frac{1}{\tau}\right)}$$

The variable R_{bb} represents the relative marginal production cost of the *bb* supply chain for *cb* firms, or $M_{cb \rightarrow bb} / M_{cb \rightarrow cb}$. Likewise, R_{cc} represents the relative marginal production cost of the *cc* supply chain for *cb* firms.

Equation (12) is the regional content of the imports of country *a* if the inequality in (6) holds and *cb* firms shift to supply chain *cc*, moving production out of the FTA region.

$$(12) \quad RC_a = \frac{S_{bb} + S_{cb}(1-\delta) (\tau)^{-\sigma} (D_{cb})}{S_{bb} + S_{cb}(1-\delta) (\tau)^{-\sigma} + S_{cb} \delta (R_{cc})^{-\sigma} + S_{cc} \left(\frac{1}{\tau}\right)}$$

If neither of the inequalities in (5) and (6) hold, then the firms will continue with its *cb* supply chain persists under the revised ROO.

and regional content will be described by equation (3).

Finally, we consider the effect on the market price index in country a and the volume of total industry imports into the country. The variable \hat{P} in equation (13) is the proportional increase in the market price index in country a if none of the firms adjusts its supply chain ($\delta = 0$).

$$(13) \quad \hat{P} = \left(\frac{S_{bb} + S_{cc} + S_{cb}(\tau)^{1-\sigma}}{S_{bb} + S_{cc} + S_{cb}} \right)^{\frac{1}{1-\sigma}} - 1$$

In this case, the effect on the market price index depends on the initial shares of the three supply chains, as well as the magnitude of the tariff rate preference.¹³

Equation (14) is the proportional increase in the market price index in country a if a share $\delta > 0$ of the cb firms have approximately the same fixed costs across countries and adopt the supply chain with the lowest marginal production costs under the revised ROO.

$$(14) \quad \hat{P} = \left(S_{bb} + S_{cc} + S_{cb} \left((1-\delta)(\tau)^{1-\sigma} + \delta (\min[\tau, \tau R_{cc}, R_{bb}])^{1-\sigma} \right) \right)^{\frac{1}{1-\sigma}} - 1$$

When $\delta > 0$, the magnitude of the price effect depends on the initial shares of the three supply chains, the magnitude of the tariff rate preference, the relative costs for firms that initially have cb supply chains (but not the relative costs of any other types of firms), and the share of cb firms with approximately the same fixed costs across countries. The increase in the market price index is mitigated if some of the firms relocate production.

Finally, the volume of total imports into country a falls by the same percentage that the market price index rises, since total demand for the products of the industry has a price elasticity of negative one.

3. Simulations

Table 2 reports a series of simulations of the economic effects of the change in the ROO, for various data inputs and parameter values. In the first column, the comparison of marginal supply costs (including the tariff) leads cb firms to switch to bb supply chains, sourcing completely within the region. The increase in the market price index in country a is largest if no firms change their supply

¹³ This calculation also does not require cost data for most of the cells in Table 1. We explicitly derive equations (13) and (14) in the Technical Appendix.

chain in response to the change in the ROO ($\delta = 0$). In this case, there is only a small increase in regional content, since there is only adjustment on the intensive margin of trade. If relocation occurs, the price effect is partly mitigated, while regional content increases more significantly. In this case, there is adjustment in both the extensive and intensive margins of trade.

In the second column of Table 2, cost-minimizing relocation leads a share δ of the *cb* firms to switch to *cc* supply chains, sourcing completely outside of the region. If no firms change their supply chains ($\delta = 0$), the effects on prices and regional content are the same as the simulation in the first column. However, if relocation occurs there is less mitigation of the price increase (compared to the first column) and regional content declines below the level under the initial ROO.

In the final column of Table 2, cost-minimization does not lead the *cb* firms to change their supply chains. In this case, the price effect is not mitigated regardless of the value of δ , and there is only adjustment on the intensive margin of trade.

Table 2: Simulations of the Economic Effects

Data Inputs and Parameters	Benchmark Move to <i>bb</i>	Variant 1 Move to <i>cc</i>	Variant 2 Stay in <i>cb</i>
N_{bb}	2	2	2
N_{cb}	2	2	2
N_{cc}	2	2	2
S_{bb}	0.33	0.33	0.33
S_{cb}	0.33	0.33	0.33
S_{cc}	0.34	0.34	0.34
R_{bb}	1.05	1.10	1.10
R_{cc}	1.10	0.95	1.10
D_{cb}	0.5	0.5	0.5
τ	1.1	1.1	1.1
σ	5	5	5
Regional Content (%)			
Initial	51.55	51.55	51.55
No Adjustment of Supply Chains ($\delta = 0.0$)	51.78	51.78	51.78
Partial Adjustment of Supply Chains ($\delta = 0.5$)	59.39	43.90	51.78
Full Adjustment of Supply Chains ($\delta = 1.0$)	66.53	36.55	51.78
Price Increases (%)			
No Adjustment of Supply Chains ($\delta = 0.0$)	2.89	2.89	2.89
Partial Adjustment of Supply Chains ($\delta = 0.5$)	2.22	2.14	2.89
Full Adjustment of Supply Chains ($\delta = 1.0$)	1.57	1.42	2.89

As a sensitivity analysis, Table 3 repeats the simulations in Table 2, but with a lower elasticity of substitution. The changes in regional content requirements are a little lower than their counterparts in Table 2. The price effect is larger for all values of δ .

Table 3: Sensitivity Analysis, Lowering the Elasticity of Substitution

Data Inputs and Parameters	Variant 3 Move to <i>bb</i>	Variant 4 Move to <i>cc</i>	Variant 5 Stay in <i>cb</i>
N_{bb}	2	2	2
N_{cb}	2	2	2
N_{cc}	2	2	2
S_{bb}	0.33	0.33	0.33
S_{cb}	0.33	0.33	0.33
S_{cc}	0.34	0.34	0.34
R_{bb}	1.05	1.10	1.10
R_{cc}	1.10	0.95	1.10
D_{cb}	0.5	0.5	0.5
τ	1.1	1.1	1.1
σ	4	4	4
Regional Content (%)			
Initial	51.55	51.55	51.55
No Adjustment of Supply Chains ($\delta = 0.0$)	51.74	51.74	51.74
Partial Adjustment of Supply Chains ($\delta = 0.5$)	59.59	43.67	51.74
Full Adjustment of Supply Chains ($\delta = 1.0$)	67.02	36.06	51.74
Price Increases (%)			
No Adjustment of Supply Chains ($\delta = 0.0$)	2.99	2.99	2.99
Partial Adjustment of Supply Chains ($\delta = 0.5$)	2.28	2.20	2.99
Full Adjustment of Supply Chains ($\delta = 1.0$)	1.59	1.44	2.99

Table 4 repeats the simulations again with a larger number for firms that have a *cb* supply chain under the initial ROO. The increase in the market price index is much larger in Table 4 than the comparable estimates in Table 2, since there are more *cb* firms affected by the change in the ROO. The changes in regional content are larger (in absolute value) for the variants that involve firms

moving from a *cb* supply chain to *bb* or *cc* supply chains.

Table 4: Sensitivity Analysis, with a Larger Number of *cb* Firms

Data Inputs and Parameters	Variant 6 Move to <i>bb</i>	Variant 7 Move to <i>cc</i>	Variant 8 Stay in <i>cb</i>
N_{bb}	2	2	2
N_{cb}	4	4	4
N_{cc}	2	2	2
S_{bb}	0.33	0.33	0.33
S_{cb}	0.33	0.33	0.33
S_{cc}	0.34	0.34	0.34
R_{bb}	1.05	1.10	1.10
R_{cc}	1.10	0.95	1.10
D_{cb}	0.5	0.5	0.5
τ	1.1	1.1	1.1
σ	5	5	5
Regional Content (%)			
Initial	51.16	51.16	51.16
No Adjustment of Supply Chains ($\delta = 0.0$)	51.44	51.44	51.44
Partial Adjustment of Supply Chains ($\delta = 0.5$)	63.19	39.32	51.44
Full Adjustment of Supply Chains ($\delta = 1.0$)	73.85	28.46	51.44
Price Increases (%)			
No Adjustment of Supply Chains ($\delta = 0.0$)	4.41	4.41	4.41
Partial Adjustment of Supply Chains ($\delta = 0.5$)	3.35	3.24	4.41
Full Adjustment of Supply Chains ($\delta = 1.0$)	2.35	2.13	4.41

4. Conclusion

The goal of this paper is to take a difficult modeling problem and try to make it manageable, by adopting certain assumptions that reduce the data requirements of the model while still including elements essential to an economic analysis of changes in the rules of origin. The approach is to identify the set of firms with supply chains that are directly affected by the changes in the ROO (firms with supply chains that meet the initial ROO but will not meet the revised ROO), count them, and estimate their market shares before the policy change. The model requires data on the cost of other supply chains not currently in use, but only for these directly affected firms, not for all firms in the industry.¹⁴ The model also requires a basic comparison of the firms' fixed costs of locating in different countries.

We conclude with a discussion of potential directions for developing the modeling framework. It is straightforward to add more markets, stages of production, and supply chains in order to fit the model to a specific industry. We could also extend the model to include many national consumer markets served by the same firms and assume that the fixed costs for each production location are shared across all of the markets served. This would link the sourcing decisions across the consumer markets and the firms' sourcing decisions would be more complex. For example, firms that have sourced part of their content within the region and part outside the region but mostly serve consumer markets outside the region will be less likely to increase their regional content in response to an increase in regional content requirements. Finally, we could analyze the policy changes in a general equilibrium setting, in which the firms' marginal costs of production of each stage in each location are endogenous. This extension would significantly increase the data requirements of the model, even if the analysis remained focused on a specific industry, since the costs of every one of the supply chain alternatives would be affected in the general equilibrium model.

¹⁴ If there are practical data limitations, it is possible to use the current costs for firms with the other supply chains as a proxy for the costs that would face a relocating firm; however, there is not a revealed cost argument for why they would be a good proxy.

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Technical Appendix

Derivation of the Regional Content Measure

Equation (1) provides a formula for overall regional content under the initial ROO. The term

$N_{bb} q_{bb \rightarrow bb} \left(\frac{\sigma}{\sigma-1} \right) M_{bb \rightarrow bb}$, for example, represents the value of products from the bb supply chain. The variable $q_{z \rightarrow xy}$ represents the volume of product from type z firms using supply chain xy , and the variable D_{cb} represents the ratio of the value added in the downstream production process in country b to the total value of the product from the cb supply chain. Equation (A1) substitutes the expenditure shares in each supply chain, S_{xy} into equation (1). To convert the expenditure share S_{cc} into a share of the value production, we divide the expenditure share by the tariff factor τ in equation (A1).

$$(A1) \quad RC_a = \frac{S_{bb} + S_{cb} (D_{cb})}{S_{bb} + S_{cb} + S_{cc} \left(\frac{1}{\tau} \right)}$$

Equation (A1) corresponds to equation (2) in Section 2.

Equation (3) is overall regional content after the change in the ROO if no firms change their supply chains, for example if all firms have a significant fixed cost advantage in their location under the initial ROO. In this case, there is a reduction in $q_{cb \rightarrow cb}$ relative to its value under the initial ROO. There is also an increase in the market price index, but since this price increase has the same effect on the quantity demanded of imports from all of the supply chains, it does not change the regional content ratio. The reduction in $q_{cb \rightarrow cb}$ is reflected in the additional $(\tau)^{-\sigma}$ factors in equation (A2).

$$(A2) \quad RC_a = \frac{S_{bb} + S_{cb} (D_{cb}) (\tau)^{-\sigma}}{S_{bb} + S_{cb} (\tau)^{-\sigma} + S_{cc} \left(\frac{1}{\tau} \right)}$$

Equations (A3) and (A4) are the regional content measures after the change in ROO when some firms have approximately the same fixed costs across locations. These ratios reflect the change in the number of firms in each supply chain configuration, assuming that a share δ of the cb firms have approximately the same fixed costs across locations. They also reflect the change in $q_{cb \rightarrow cb}$. Equation (A3) applies if the cb firms that move adopt a bb supply chain.

$$(A3) \quad RC_a = \frac{S_{bb} + S_{cb} (1-\delta) (\tau)^{-\sigma} (D_{cb}) + S_{cb} \delta (R_{bb})^{-\sigma}}{S_{bb} + S_{cb} (1-\delta) (\tau)^{-\sigma} + S_{cb} \delta (R_{bb})^{-\sigma} + S_{cc} \left(\frac{1}{\tau} \right)}$$

Equation (A4) applies if the *cb* firms that move adopt a *cc* supply chain.

$$(A4) \quad RC_a = \frac{S_{bb} + S_{cb}(1-\delta)(\tau)^{-\sigma}(D_{cb})}{S_{bb} + S_{cb}(1-\delta)(\tau)^{-\sigma} + S_{cb}\delta(\tau R_{cc})^{-\sigma} + S_{cc}\left(\frac{1}{\tau}\right)}$$

Equations (A3) and (A4) correspond to equations (11) and (12) in Section 2.

Derivation of the Price Increases

Equation (A5) represents the price effects when $\delta = 0$.

$$(A5) \quad \hat{P} = \left(\frac{N_{bb}(M_{bb \rightarrow bb})^{1-\sigma} + N_{cc}(\tau M_{cc \rightarrow cc})^{1-\sigma} + N_{cb}(\tau M_{cb \rightarrow cb})^{1-\sigma}}{N_{bb}(M_{bb \rightarrow bb})^{1-\sigma} + N_{cc}(\tau M_{cc \rightarrow cc})^{1-\sigma} + N_{cb}(M_{cb \rightarrow cb})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}}$$

The Dixit-Stiglitz demand assumptions and the constant mark ups of price over marginal cost imply the following relationships between marginal costs and market shares under the initial ROO:

$$(A6) \quad \frac{S_{bb}}{S_{cb}} = \frac{N_{bb}(M_{bb})^{1-\sigma}}{N_{cb}(M_{cb})^{1-\sigma}}$$

$$(A7) \quad \frac{S_{cc}}{S_{cb}} = \frac{N_{cc}(\tau M_{cc})^{1-\sigma}}{N_{cb}(M_{cb})^{1-\sigma}}$$

Equations (A8) and (A9) invert equations (A6) and (A7), respectively.

$$(A8) \quad N_{bb}(M_{bb})^{1-\sigma} = \left(\frac{S_{bb}}{S_{cb}} \right) N_{cb}(M_{cb})^{1-\sigma}$$

$$(A9) \quad N_{cc}(\tau M_{cc})^{1-\sigma} = \left(\frac{S_{cc}}{S_{cb}} \right) N_{cb}(M_{cb})^{1-\sigma}$$

Then we substitute the expressions from equation (A8) and (A9) into equation (A5). We cancel the common terms in the numerator and denominator of this ratio, and the result is the proportional change in the market price index in equation (A10).

$$(A10) \quad \hat{P} = \left(\frac{S_{bb} + S_{cc} + S_{cb}(\tau)^{1-\sigma}}{S_{bb} + S_{cc} + S_{cb}} \right)^{\frac{1}{1-\sigma}} - 1$$

Equation (A10) corresponds to equation (13) in Section 2.

Finally, equation (A11) is the proportional change in the market price index when $\delta > 0$.

$$(A11)$$

$$\hat{P} = \left(\frac{N_{bb} (M_{bb \rightarrow bb})^{1-\sigma} + N_{cc} (\tau M_{cc \rightarrow cc})^{1-\sigma} + (1-\delta) N_{cb} (\tau M_{cb \rightarrow cb})^{1-\sigma} + \delta N_{cb} (\min[\tau M_{cb \rightarrow cb}, \tau M_{cb \rightarrow cc}, M_{cb \rightarrow bb}]^{1-\sigma})}{N_{bb} (M_{bb \rightarrow bb})^{1-\sigma} + N_{cc} (\tau M_{cc \rightarrow cc})^{1-\sigma} + N_{cb} (M_{cb \rightarrow cb})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}}$$

Again we substitute equations (A8) and (A9) and cancel common terms. The result is equation (A12), which corresponds to equation (14) in Section 2.

$$\text{(A12)} \quad \hat{P} = \left(S_{bb} + S_{cc} + S_{cb} \left((1-\delta)(\tau)^{1-\sigma} + \delta (\min[\tau, \tau R_{cc}, R_{bb}])^{1-\sigma} \right) \right)^{\frac{1}{1-\sigma}} - 1$$