BORDER MEASURES AND COMPLIANCE WITH INTERNATIONAL POLLUTION CONTROLS

David Riker

ECONOMICS WORKING PAPER SERIES
Working Paper 2021–05–D

U.S. INTERNATIONAL TRADE COMMISSION
500 E Street SW
Washington, DC 20436

May 2021

Thanks to Dylan Carlson and Tricia Mueller for helpful comments on this paper.

Border Measures and Compliance with International Pollution Controls
David Riker
Economics Working Paper 2021–05–D
May 2021

Abstract

We develop an industry-specific model of international trade that quantifies the effects of pollution controls on exports, prices, and profits of firms located in different countries. We use the model to analyze the potential for border measures to motivate compliance with international pollution controls. As an illustrative example, we apply the model to international and domestic trade data for the global primary metals industry and quantify the economic effects of a hypothetical U.S. border measure on the likelihood of pollution abatement in China.

David Riker
Research Division
david.riker@usitc.gov

1 Introduction

Trade policy is a tool for motivating compliance with international pollution controls, to address concerns about leakage and loss of international competitiveness. For example, one country might urge another to adopt costly pollution controls on production processes in the second country. If the two countries cannot reach a cooperative agreement on pollution abatement, can a narrowly targeted border measure on non-compliant imports into the first country motivate the second country to comply with the pollution controls? While trade policy is an indirect way to address pollution control, it might be the best option available, since national sovereignty typically limits direct enforcement of controls across international borders.

There is a large literature that uses models to study the economic effects of pollution abatement costs and border measures. Recent examples include partial equilibrium models of border measures like Eyland and Zaccour (2014), Anouliès (2014), Sheldon and McCorriston (2017), and Al Khourdajie and Finus (2020) and computable general equilibrium models like Babiker and Rutherford (2005) and Fischer and Fox (2012). Condon and Ignaciuk (2013) is a useful review of the earlier literature on border measures.[1]

In this paper, we contribute to this literature by developing an industry-specific model of international trade that quantifies the effects of border measures and pollution abatement on exports, prices, and the profitability of firms in each country. The model is designed as a practical tool for trade policy analysis, with tractable equations and modest data requirements. Section 2 presents the modeling framework. Section 3 uses the model to analyze the economic effects of border measures and pollution controls: higher abatement costs and large third-country markets both magnify the effects of these policies on exports, prices and

[1] Ederington, Levinson and Minier (2005) and Levinson and Taylor (2008) are econometric studies that show that pollution controls can have significant effects on international trade flows, though they do not address the issue of pollution-related border measures.

profits. Then we use the model to analyze the potential for border measures to motivate compliance when there is imperfect monitoring of pollution abatement across borders. Compliance with pollution controls is more likely if the probability of detecting non-compliance is higher and third-country markets are smaller.

Sections 4 provides an illustrative example. We apply the model to data on international trade and domestic shipments in the primary metals industry, which includes energy-intensive steel and aluminum manufacturing. First, we use the model to estimate the economic effects of a hypothetical border measure imposed by the United States on imports from China that exactly matches the cost of complying with the pollution control. Then we estimate how large of a border measure would be needed to motivate Chinese firms to comply with the costly pollution controls.

Section 5 discusses extensions of the model that include longer-run investment decisions about production lines and the relocation of production. Section 6 concludes with suggestions for future research.

2 Modeling Framework

We analyze the effects of border measures and pollution controls on international trade using a partial equilibrium simulation model that focuses on a specific industry. Even if a pollution control policy is broadly applied to many industries, there are often narrow exceptions to the policy that can be usefully analyzed with an industry-specific model.

Firms in the industry face CES demands that distinguish between products from individual firms located in several different countries, with an elasticity of substitution equal to σ. International trade costs include an ad valorem freight factor for shipments from country i to country j, $d_{ij} > 1$, and a border measure that takes the form of an ad valorem tariff on country j's imports from country i, represented by the trade cost factor $\tau_{ij} > 1$.[2] Equation (1) is the sales in country j of one of the symmetrically differentiated firms that produce in country i.

$$X_{ij} = b_i \; E_j \; (P_j)^{\sigma \, - \, 1} \; (p_i \; d_{ij} \; \tau_{ij})^{1 \, - \, \sigma} \tag{1}$$

p_i is the producer price of industry products from country i, E_j is total expenditures on the products of the industry in country j, and b_i is a preference asymmetry parameter for the products of firms in country i. P_j is the industry's CES price index in country j.

$$P_j = \left(\sum_i \; N_i \; b_i \; (p_i \; d_{ij} \; \tau_{ij})^{1 \, - \, \sigma} \right)^{\frac{1}{1 \, - \, \sigma}} \tag{2}$$

There is a continuum of firms producing in country i supplying symmetrically differentiated products, with fixed mass N_i. The firms engage in Bertrand competition, taking the industry price index in each national market as given. The model focuses on the short run, in the sense that the number of firms and the location of their production are taken as given. Given these assumptions, each firm's price is a constant mark-up over its marginal costs.

There are constant marginal costs of production m_i and an additional ad valorem marginal cost factor $\lambda_i > 1$ if a firm in country i complies and adopts the pollution controls.

$$p_i = \left(\frac{\sigma}{\sigma \; - \; 1} \right) \; m_i \; \lambda_i \tag{3}$$

There is also a fixed cost of producing in country i, f_i. We assume that this fixed cost is large enough that the production of each firm is located in a single country, despite international trade costs, to achieve economies of scale. There may be an additional fixed cost of complying with pollution controls, $\kappa_i > 0$.

We assume that each firm can separate its production processes, with one production

[2] The border measure is only applied to imports of industry products that do not comply with the pollution controls.

line that supplies its domestic market and another distinct production line that supplies its export markets. Equation (4) is the total export profits of a firm that produces in country i.

$$\pi_i \; (\tau_{ij}, \lambda_i) = \sum_{j \neq i} \left(\frac{1}{\sigma} \; E_j \; \left(b_i \; \frac{(m_i \; \lambda_i \; d_{ij} \; \tau_{ij})^{1 \; - \; \sigma}}{\sum_{k \neq i} b_k \; (m_k \; \lambda_k \; d_{kj} \; \tau_{kj})^{1 \; - \; \sigma}} \right) \right) \; - \; f_i \; - \; \kappa_i \qquad (4)$$

We assume that there are three countries: A, B, and C. Country A uses the border measure to motivate country B to comply with the pollution controls, so $\tau_{BA} > 1$ for non-compliant exports from B and A. Country C, the third country, already complies with the pollution controls and is an additional export market for country A and B.

3 Analysis of Economic Effects

In the model, the costs of pollution controls in country B are represented by variable cost factor λ_B and fixed cost factor κ_B.[3] The model does not try to quantify the social benefits that lead country A to try to motivate producers in country B to comply with the pollution controls. Instead, we take the pollution controls advocated by A as given and focus on the question of compliance in B and the resulting economic effects on exports, prices, and profits in each of the countries.[4] There may be social or political reasons why B would adopt or reject pollution controls regardless of the economic incentives created by border measures. The model focuses instead on the case where economic incentives have the potential to influence pollution abatement decisions on the margin.

[3]While most of the literature cited above focuses on the control of carbon dioxide emissions, the model could also be applied to costly abatement of other types of pollutants.

[4]In contrast, much of the game-theoretical literature on this topic focuses on the process of policy formation. Examples include Anouliès (2014), Eyland and Zaccour (2014), and Al Khourdajie and Finus (2020).

3.1 Effects of Pollution Control Costs

First, we use the model to estimate the economic effects of variable abatement costs in country B. An increase in λ_B reduces exports from B to the other two countries ($\frac{dX_{BA}}{d\lambda_B} < 0$ and $\frac{dX_{BC}}{d\lambda_B} < 0$) and increases exports from A ($\frac{dX_{AB}}{d\lambda_B} > 0$ and $\frac{dX_{AC}}{d\lambda_B} > 0$). Costly abatement in B also increases exports from C to A ($\frac{dX_{CA}}{d\lambda_B} > 0$) but reduces total exports to A ($\frac{d(X_{BA}+X_{CA})}{d\lambda_B} < 0$). An increase in variable abatement costs in B increases the industry price indices in A and B ($\frac{dP_A}{d\lambda_B} > 0$ and $\frac{dP_B}{d\lambda_B} > 0$). It reduces the profits of producers in B ($\frac{d\pi_B}{d\lambda_B} < 0$) and increases the profits of producers in A ($\frac{d\pi_A}{d\lambda_B} > 0$).

The economic effects of a fixed abatement cost κ_B are quite different. An additional fixed cost has no effect on exports or prices in the short run, though it reduces the profits of firms that produce in B. Eventually, over the longer run, it might lead firms to exit the industry or to relocate, as we discuss in Section 5.

3.2 Effects of Border Measures

Next, we estimate the effects of a border measure on the exports of B in the event of non-compliance in B. $\tau_{BA} > 1$ reduces exports from B to A ($\frac{dX_{BA}}{d\tau_{BA}} < 0$) but has no effect on exports from A to either country in the model ($\frac{dX_{AB}}{d\tau_{BA}} = 0$ and $\frac{dX_{AC}}{d\tau_{BA}} = 0$). There is an increase in the industry price index in A ($\frac{dP_A}{d\tau_{BA}} > 0$) but not in either of the other countries. The border measure τ_{BA} increases the profits of producers in A and C and reduces the profits of producers in B.

These effects are magnified if the border measure is applied to imports of A and C in a coordinated way, with $\tau_{BA} = \tau_{BC} > 1$. In this case, the effects on X_{BA}, X_{AB}, X_{CA}, P_A, and P_C are the same as a border measure only applied in A, but the coordinated border measure magnifies the increase in π_A and the reduction in π_B. In addition, it reduces X_{BC} while increasing X_{AC}.

3.3 Effects of a Border Measure Set at λ_B

In this section, we compare the economic effects of a border measure on exports from B to A to the economic effects of compliance with pollution controls in B when the border measure is set exactly equal to λ_B. Specifically, we compare the economic effects when $\tau_{BA} = 1.1$ to the effects when $\lambda_B = 1.1$.[5]

The equal-sized border measure and the variable compliance cost have the same effects on exports from B to A and from C to A and the same effect on the price index in A. With the border measure, however, there is not a reduction in X_{BC}, because the effect on the cost competitiveness of producers in B is limited to the national market with the border measure, in this case A. The border measure also does not increase exports from A to B or from A to C, unlike costly pollution abatement in B. Under the border measure, there would be a smaller increase in the profits of firms that produce in A and a smaller decrease in the profits of firms that produce in B. For these reasons, a border measure equal to 1.1 would not be large enough to motivate compliance with pollution abatement cost equal to 1.1, though an equal-sized border measure may be the maximum border measure available to A under its WTO commitments.[6]

3.4 A Border Measure Sufficient to Motivate Compliance

Next, we analyze how large a border measure would need to be to motivate the compliance of firms in country B with the pollution controls advocated by country A, assuming that the border measure is triggered by the detection of non-compliance of producers in B. We assume that there is imperfect monitoring of compliance in B, with a probability of detecting non-compliance equal to $\phi_B < 1$. Equation (5) implicitly defines the compliance-sufficient

[5] A cost factor of 1.1 is equivalent to a 10% adder.

[6] For example, Sheldon and McCorriston (2017) and Al Khourdajie and Finus (2020) suggest that the non-discrimination and competitive equality principles of the WTO might impose a ceiling on border measures equivalent to the abatement cost.

rate of the border measure, $\tilde{\tau}_{BA}$.

$$\pi_B\ (\tilde{\tau}_{BA}, 1)\ \phi_B\ +\ \pi_B\ (1, 1)\ (1\ -\ \phi_B) = \pi_B\ (1, \lambda_B) \tag{5}$$

More effective monitoring of compliance in B (a higher probability ϕ_B) reduces the compliance-sufficient level of the border measure: as ϕ_B increases, $\tilde{\tau}_{BA}$ declines. As long as $\tau_{BA} \geq \tilde{\tau}_{BA}$, there is compliance with the pollution controls and the export, price, and profit effects are set by λ_B, not by τ_{BA}. The border measure does not determine the magnitude of the economic effects, because it is threatened but not applied in equilibrium (as long as $\tau_{BA} \geq \tilde{\tau}_{BA}$).[7] As long as there is not a binding ceiling on the border measure, the compliance-sufficient level of τ_{BA} will be higher when third-country markets are large and when the border measure is coordinated across multiple countries. Even though fixed costs of compliance ($\kappa_B \geq 0$) will not affect exports or prices in the short run, they do reduce π_B, and this increases the compliance-sufficient level of the border measure.

Finally, if a firm cannot separate its production lines that supply its domestic market from the lines that supply its export markets and if its domestic market is much larger, then the level of the border measure sufficient to motivate compliance will be impractically high.

4 Application to Trade in Primary Metals

In this section, we apply the model to international trade in the primary metals manufacturing industry, which is an energy-intensive and trade-exposed industry. We do not attempt to develop a specific engineering estimate of the industry's variable pollution abatement costs; instead, we assume that $\lambda_{CH} = 1.1$ for the sake of the model simulations. We estimate the magnitude of the economic effects relative to this hypothetical value and focus on how the magnitudes of the economic effects are affected by the pattern of trade and by the elasticity

[7] Anouliès (2014) and Eyland and Zaccour (2014) also model border measures as credible threats.

of substitution in primary metals.

We extend the modeling framework slightly to include four country-groups: the United States, China, the European Union, and an aggregate of the Rest of the World. To calculate country shares in primary metals trade, we use the 2014 international trade and domestic shipment data for the industry from the World Input-Output Database (WIOD) in Table 1.[8]

Table 1: Industry Exports and Domestic Shipments (in Millions of USD)

Source Country	To the United States	To China	To the EU	To the Rest of the World
United States	250,854	1,226	3,648	26,177
China	7,073	1,724,311	8,629	71,681
European Union	12,357	11,010	389,375	71,961
Rest of the World	70,273	111,678	72,717	1,669,711

For the elasticity of substitution, we use $\sigma = 5.9$, the industry-specific econometric estimate in Hertel, Hummels, Ivanic and Keeney (2007).

Table 2 reports model simulations for different values of the policy variables. Higher variable costs of compliance and border measures both reduce exports from China to some markets and leave China's exports to other markets unchanged. They increase exports from the United States to some of the markets. There are larger effects from compliance than from equal-sized border measures, since compliance affects China's competitiveness in more of its export markets. The negative effects on the profits of Chinese producers are much greater with compliance than with the equal-sized border measure, and the positive effects on the profits of U.S. producers are also larger with compliance.

Next, we consider the profitability of compliance in B. Table 3 reports the simulated change in expected profits of firms that produce in China from compliance and non-

[8]The data are publicly available at `wiod.org` and are described in Timmer, Dietzenbacher, Los, Steher and de Vries (2015).

Table 2: Model Simulations for the Industry

	v.1	v.2	v.3
Policy Measures			
λ_{CH}	**1.1**	1.0	1.0
$\tau_{CH,US}$	1.0	**1.1**	**1.1**
$\tau_{CH,EU}$	1.0	1.0	**1.1**
Change in Exports (in Millions of USD)			
From China to the US	-2,605	-2,605	-2,605
From China to the EU	-3,183	0	-3,183
From China to the Rest of the World	-26,084	0	0
From the US to China	0	0	0
From the US to the EU	25	0	14
From the US to the Rest of the World	386	0	0
Percent Change in Price Index (%)			
Consumers in the US	0.16	0.16	0.16
Consumers in the EU	0.14	0.00	0.14
Consumers in China	0.00	0.00	0.00
Consumers in the Rest of the World	0.30	0.00	0.00
Change in Profits (in Millions of USD)			
Firms in China	-29,708	-441	-3,624
Firms in US	402	322	336

compliance, assuming that they have separate production lines for exports and domestic shipments. A larger border measure reduces expected profits with non-compliance, though non-compliance is still more profitable for Chinese firms for all of the levels of the border measure considered in Table 3.

Table 3: Separate Production Lines for Exports and Domestic Shipments

$\tau_{CH,US}$	1.0	1.1	1.2	1.3
ϕ_{CH}	0.90	0.90	0.90	0.90
λ_{CH}	1.1	1.1	1.1	1.1
Expected Change in Profits of Firms in China (in Millions of USD)				
From Non-Compliance	307,067	306,669	306,435	306,291
From Compliance	301,665	301,665	301,665	301,665

If there is no uncertainty about compliance ($\phi_{CH} = 1$) and there is a dedicated Chinese production line that supplies the United States, then the compliance-sufficient border measure is exactly equal to λ_{CH}. If either $\phi_{CH} < 1$ or the production line is not dedicated to supplying the United States, then the compliance-sufficient border measure is greater than λ_{CH}.

The separability of production lines that supply different national markets is a significant determinant of the magnitude of the economic effects and the level of a compliance-sufficient border measure. If there *were not* separate production lines for exports and domestic shipments (more pooling than in the simulations in Table 2), then the decrease in the profitability of firms in China would be much larger, because China's domestic market for primary metals is a large share of the country's global sales. In this case, the compliance-sufficient border measure would be impractically high.

At the other extreme, further separation of production lines, with a dedicated production line supplying *each* national export market, would make compliance more likely, because firms producing in China would not be losing profits in third-country markets when they adopted pollution controls to avoid U.S. border measures. This alternative scenario is illustrated in Table 4, which reports the simulated expected profits of firms in China from compliance and non-compliance. These simulations assume that there is a separate production line for each export market. In this case, $\tilde{\tau}_{CH,US}$ is greater than 1.1 but less than 1.2. To satisfy equation (5), $\tilde{\tau}_{CH,US}$ is 1.1155.

Table 4: Separate Production Lines for Each Export Market

$\tau_{CH,US}$	1.0	1.1	1.2	1.3
ϕ_{CH}	0.90	0.90	0.90	0.90
λ_{CH}	1.1	1.1	1.1	1.1
Expected Change Profits in China (in Millions of USD)				
From Non-Compliance	307,067	306,669	306,435	306,291
From Compliance	306,625	306,625	306,625	306,625

Compliance is more likely if the production lines are separable, and compliance is presumably the environmental goal of the border measure. However, even though separability of production lines increases the likelihood of compliance, it also narrows the application of pollution abatement, and so it can actually reduce global abatement. If the production lines are separate, then the compliance-sufficient border measure is lower when the United States and the EU coordinate on border measures ($\tau_{CH,US} = \tau_{CH,EU} > 1$). On the other hand, if the production lines are not specific to each export market, as in Table 3, there will not be compliance with a coordinated border measures even if $\tau_{CH,US}$ and $\tau_{CH,US}$ are both 1.3.

5 Model Extensions for the Longer Run

In this section, we discuss two extensions of the model that address the effects of the policies on investment decisions over a longer time horizon.

5.1 Creating Separate Production Lines for Exports

In the model simulations in Section 4, we demonstrated that the separability of firms' production lines that supply different export markets affects the magnitude of the economic effects of the policies and the level of compliance-sufficient border measure, assuming that the production lines were firmly established in the past and do not adjust to the policy changes considered in these simulations.

We can extend the model to allow the firms to restructure their production lines in response to border measures or pollution controls, starting from a baseline with a common production line that supplies all of the export markets. In this case, the border measure creates an incentive for Chinese firms to create separate production lines, a more costly compliant one for supplying the United States and a less costly non-compliant one for supplying other export markets without border measures. This separation of production lines would mitigate the increase in variable costs of supply but would also reduce global pollution abatement. There would likely be additional fixed costs associated with separate production lines that would enter into the profit calculations, so this extension of the model would require significant additional data inputs.

5.2 International Relocation

The model can also be extended to analyze the international relocation of firms in response to border measures over the longer run, while still holding the global number of firms constant and assuming that fixed costs of production in each location are large enough that each firm still chooses a single production location to achieve economies of scale rather than replicating this fixed cost in multiple countries.[9]

As earlier investments in production in one country depreciate, the firms might reconsider

[9]This is a simplifying assumption that can be relaxed to consider alternative scenarios.

where they can most profitably produce to supply their markets, given trade costs and pollution abatement policies in each country. With relocation a possibility, a fixed compliance cost κ_B that reduces the profitability of producing in B creates an additional incentive to move *from* B, or to hold off relocating *to* B from a country with high costs of pollution controls. While variable compliance costs in B will increase the attractiveness of locating in other countries, they might not be enough to make relocation profitable. Likewise, while border measures will make tariff-jumping relocation of production to A more attractive, they might not be enough to lead to relocation.[10]

Even if there is relocation of firms in the industry, the consequences for variable costs and producer prices are ambiguous. For example, a firm might relocate to increase profits by moving to a location with higher variable costs but lower fixed costs, leading to higher prices; or by moving to a location with lower variable costs but higher fixed costs, leading to lower prices.[11] Additional data on fixed costs would be required to calculate the economic effects of border measures and pollution controls when international relocation is a possibility.

6 Conclusions

The effects of pollution control costs on exports, prices, and profits depend on whether pollution abatement increases variable costs or fixed costs, at least in the short run. The effects also depend on the relative size of third-country markets where the firms compete, and on the quality of cross-border monitoring of compliance. Border measures that match the magnitudes of the variable costs of pollution control costs will have smaller positive effects on the country imposing the border measure and smaller negative effects on the country facing the border measure compared to compliance, and will probably not be sufficient to motivate compliance.

[10] Tariff jumping investments are discussed in more detail in Riker and Schreiber (2019).
[11] This ambiguity in price effects is analyzed in Riker (2020).

The minimum compliance-sufficient border measure is higher the larger the variable cost of abatement. It is smaller when third-country markets are relatively small, and when more effective international monitoring of compliance increases the probability of detecting non-compliance. If border measures do not motivate compliance, then they might protect the domestic industry from import competition but not meet environmental goals for pollution abatement. When production lines can be separated and dedicated to specific national markets, compliance is more likely, but global pollution abatement might be reduced.

In addition to the two extensions discussed in Section 5, the modeling framework could also be extended to address the economic effects of border measures and pollution abatement costs on downstream industries. For example, pollution abatement in the electric power industry can affect the cost competitiveness of downstream manufacturing industries. Lastly, the modeling framework is broadly applicable to analysis of compliance with other types of international regulations and standards, as long as the data inputs of the model are available, including country shares of international and intra-national shipments, an estimate of the elasticity of substitution in demand, and an estimate of the variable production costs of complying with the specific regulations or standards.

References

Al Khourdajie, A. and Finus, M. (2020). Measures to Enhance the Effectiveness of International Climate Agreements: The Case of Border Carbon Adjustments, *European Economic Review* **126**: 103405.

Anouliès, L. (2014). The Strategic and Effective Dimensions of the Border Tax Adjustment, *Journal of Public Economic Theory* **17**(6): 824–847.

Babiker, M. and Rutherford, T. (2005). The Economic Effects of Border Measures in Subglobal Climate Agreements, *Energy Journal* **26**(4): 99–125.

Condon, M. and Ignaciuk, A. (2013). Border Carbon Adjustment and International Trade: A Literature Review. OECD Trade and Environment Working Papers, 2013/06 (`http://dx.doi.org/10.1787/5k3xn25b386c-en`).

Ederington, J., Levinson, A. and Minier, J. (2005). Footloose and Pollution-Free, *Review of Economics and Statistics* **87**(1): 92–99.

Eyland, T. and Zaccour, G. (2014). Carbon Tariffs and Cooperative Outcomes, *Energy Policy* **65**: 718–728.

Fischer, C. and Fox, A. (2012). Comparing Policies to Combat Emissions Leakage: Border Carbon Adjustments Versus Rebates, *Journal of Environmental Economics and Management* **64**(2): 199–216.

Hertel, T., Hummels, D., Ivanic, M. and Keeney, R. (2007). How Confident Can We Be of CGE-Based Assessments of Free Trade Agreements?, *Economic Modelling* **24**: 611–635.

Levinson, A. and Taylor, M. S. (2008). Unmasking the Pollution Haven Effect, *International Economic Review* **49**(1): 223–254.

Riker, D. (2020). Modeling the Effects of Labor Standards on Trade and Wages. U.S. International Trade Commission, Economics Working Paper 2020-12-A.

Riker, D. and Schreiber, S. (2019). Modeling FDI: Tariff Jumping and Export Platforms. U.S. International Trade Commission, Economics Working Paper 2019-10-C.

Sheldon, I. and McCorriston, S. (2017). Climate Policy and Border Measures: The Case of the U.S. Aluminum Industry, *Applied Economic Perspectives and Policy* **39**(2): 242–258.

Timmer, M., Dietzenbacher, E., Los, B., Steher, R. and de Vries, G. (2015). An Illustrated Users Guide to the World Input-Output Database: the Case of Global Automotive Production, *Review of International Economics* **23**: 575–605.