Iowa State University

BICWP-2010-001

# Assessment of Environmental Impacts Embodied in U.S.-China and U.S.-India Trade and Related Climate Change Policies

Xiaodong Du, Fenxia Dong, Dermot J. Hayes,
and Tristan R. Brown

BIOBASED INDUSTRY CENTER

This paper is part of the Biobased Industry Center's Working Paper Series. The Biobased Industry Center is an interdisciplinary research center at Iowa State University.

Iowa State University
Biobased Industry Center
Biorenewables Research Laboratory
Ames, Iowa 50011-3270
www.biobasedindustrycenter.iastate.edu

# Assessment of Environmental Impacts Embodied in U.S.-China and U.S.-India Trade and Related Climate Change Policies

Xiaodong Du, Fengxia Dong, Dermot J. Hayes, and Tristan R. Brown

**Abstract:** We empirically investigate the GHG emissions embodied in the bilateral trade between the United States and China and the United States and India and their country-specific and global environmental impacts. In order to address the concerns of "level-playing-field" and carbon leakage associated with domestic carbon pricing scheme, various border carbon adjustments have been proposed in recent U.S. climate change legislation. Employing GTAP-E model, this study examines how and to what extent the proposed carbon tariffs and export subsidies potentially affect bilateral trade flow, domestic production, and the GHG emissions. Results indicate that carbon tariff effectively alleviates the impact of domestic carbon tax on vulnerable domestic industries and slightly raises their output and GHG emissions. In addition, it is also evident that a combined or full border adjustment policy has bigger impacts than an individual policy.

**Keywords:** border carbon adjustments, carbon tariff, export subsidy, GHG intensity.

**JEL classification:** Q56; Q58.

## Introduction

The interaction between international trade and the environment has become an increasingly important topic within both the academic literature and policy analysis. This is a result of deeper economic integration and world climate change concerns (e.g., Antweiler, Copeland, and Taylor 2001; Copeland and Taylor 2005). In the design of U.S. climate policy there are extensive discussions on the potential economic impact of federal legislation and multilateral international agreements. By imposing a cost on domestic greenhouse gas (GHG) emissions, proposed U.S. climate policy will adversely affect domestic carbon-intensive industries competing in both international and domestic markets. If other countries adopt less strict climate policies, producers of comparable carbon-intensive goods in such countries obtain an unfair competitive advantage by not complying with proper environmental practices. This is known as the “level-playing-field” complaint (Houser et al. 2008).

Carbon leakage could occur when U.S. GHG emission reductions resulting from a strict domestic climate policy cause an increase in GHG emissions in developing countries. It happens through the substitution of carbon-intensive goods with imported goods or through production relocation to other countries (Asselt and Brewer 2010). Furthermore, as international climate frameworks such as the Kyoto Protocol set emission reduction targets based on the location of GHG emissions rather than on the location of final consumption, several studies suggest that significant environmental impacts can be shifted from more service-oriented economies to other economies (e.g., Li and Hewitt 2008; Ackerman, Ishikawa, and Suga 2007; Pan, Phillips, and Chen 2008).

The United States, China, and India are among the world's largest emitters of GHGs. China overtook the United States to become the number one emitter in 2006, which can be largely attributed to its rapid economic growth, coal-dominated energy structure, and increasing exports (Lin and Sun 2010). China produced 6,200 million tons of carbon dioxide, while the estimated U.S. emissions were roughly 5,800 million tons. As the fourth-largest contributor to global GHG emissions, India emitted roughly 1,343 million tons in 2006. The economic relationship between the U.S. and China has expanded substantially over the past several years. Total U.S.-China trade rose from $5 billion in 1980 to $366 billion in 2009. China is now the second-largest U.S. trading partner and source for the import/export market, accounting for 14% of total U.S. trade. The United States is India's largest trading partner, with two-way trade totaling $37.64 billion in 2009, more than double the total in 2000. The massive trade flows between these large economies, especially for carbon-intensive products, have significant environmental and policy implications in both economic and environmental terms. The main purpose of this paper is to investigate empirically the GHG emissions embodied in the bilateral trade between the United States and China and the United States and India and their country-specific and global environmental impacts.

Various border carbon adjustments (BCAs) have been proposed to address carbon leakage in recent U.S. climate change legislation. The related policy options include (i) carbon tariffs, which require importers to pay an equivalent amount of carbon tax as applied to domestic producers; (ii) carbon allowances, which require importers to purchase and surrender a certain amount of emission allowances to reflect the GHG emitted in the production process (Lockwood and Whalley 2009); and (iii) export subsidies, in which the government partially or entirely reduces the number of GHG allowances owed by a domestic entity, with the reduction amount ultimately being based on the entity's quantity of exports. While carbon tariff and allowance options are intended to level the carbon playing field for U.S. producers competing in domestic markets, export subsidies are provided for U.S. exporters to alleviate their emission cost burdens and enable them to maintain competitiveness in international markets.

Because the imposition of BCAs is conditioned on whether the trade partner has imposed comparable climate policy to that of the United States, both China and India are clearly the possible targets (Houser et al. 2008). This study attempts to investigate empirically how and to what extent the proposed carbon tariffs and export subsidies potentially affect bilateral trade flow, domestic production, and the GHG emissions.

**Related Literature**

A number of recent studies have examined the carbon dioxide ($CO_2$) emissions embodied in China's exports and have estimated their contribution to China and world $CO_2$ emissions. For example, Shui and Harriss (2006) examine $CO_2$ embodied in U.S.-China trade and its contribution to national and global $CO_2$ emissions. The study suggests that the U.S. avoided a substantial amount of $CO_2$ emissions by importing Chinese goods, while production of exports for U.S. consumption is one of the primary driving forces for the emission increase in China. Applying environmental input-output analysis, Weber et al. (2008) investigated the $CO_2$ emissions in the production of exports in China in 1987-2005 and confirmed the findings in Shui and Harriss (2006). The authors indicate that the proportion of $CO_2$ emitted in production of exports increased from 12% in 1987 to 33% in 2005, largely driven by consumption in the developed world. Both Pan, Phillips, and

Chen (2008) and Lin and Sun (2010) argue that estimating China's emissions on a consumption rather than on a production basis will lower its responsibility for $CO_2$ emissions, in other words, giving rise to carbon leakage.

Economic analysis of BCAs has been conducted by various authors (see OECD 2010 for a summary of recent studies on the potential competitiveness impacts of the European Union's environmental policies). The majority of these studies use multisector static general equilibrium models to quantify the extent of these policy options. Fischer and Fox (2009) compare several policy options to combat emission leakage. Their study finds that with different economic impacts, all policy options potentially support domestic production but may not be effective at reducing global emissions. Using a computable general equilibrium (CGE) approach to quantify the policy effects, Mattoo et al. (2009) concluded that applying BCAs to both imports and exports would generally address the competitiveness concerns of countries with a high carbon price without serious consequences for developing country trade partners. In a related study, Dong and Whalley (2009) find that when BCAs involve both a carbon tariff and an export subsidy and there is no difference in emission intensities across sectors, the BCAs have a small effect on world trade, welfare, and emissions.

Our paper differs from the existing literature in several important ways. First, in contrast to the other studies, besides combustion-based $CO_2$ emissions, we account for non-$CO_2$ GHG emissions to quantify sector GHG intensity and emissions embodied in bilateral trade. While agriculture contributes over 20% of anthropogenic GHG emissions in terms of metric tons of $CO_2$ equivalent (IPCC 2001), taking these non-$CO_2$ gases into account provides a complete picture of trade-related environmental impacts. Second, by focusing on the “presumptively eligible” industries in the U.S. and imposing a carbon tariff on trading partner imports only, we evaluate the policies’ impacts in a simplified and clear way and provide a benchmark for further extension.

**Greenhouse Gas Intensity and Emissions Embodied in U.S.-China and U.S.-India Trade**

The GHG emissions embodied in bilateral trade between the U.S. and China and the U.S. and India are calculated using the Global Trade Analysis Project’s 7.0 data set (GTAP 7) for 2004 (Narayanan and Walmsley 2008) in combination with the combustion-based $CO_2$ and non-$CO_2$ GHG emissions data set (GTAP-E) (Lee 2008a, 2008b; Rose and Lee 2008). The non-$CO_2$ GHG, including nitrous oxide ($N_2O$), methane ($CH_4$), and carbon from land clearing, are largely emitted by agricultural production and related activities. The GTAP model is a static multiregion, multisector applied general equilibrium model that distinguishes 57 sectors and 113 countries and regions. The model is able to capture details of interactions between domestic sectors and international trading partners.

In the first step, GHG intensities for the covered sectors in each country are calculated by dividing each sector’s GHG emission amount by its respective GDP, resulting in the GHG intensity in metric tons of $CO_2$ equivalent per thousand dollars (Mg $CO_2$-e/\$1000). The sector GHG emissions are obtained by summing up the combustion-based $CO_2$ and non-$CO_2$ GHG emissions. In the second step, GHG emissions embodied in U.S. imports from China and from India are calculated by multiplying the GHG intensity in the Chinese/Indian industries by the related volumes of U.S. import flow. The GHG emissions embodied in U.S. exports to China/India are calculated in the same manner.

Results of the GHG intensities for the benchmark year of 2004 indicate that all major industrial sectors in China and India have higher GHG intensities than their U.S. counterparts. The average GHG intensities for China, India, and the U.S. are roughly 2.6, 1.6, and 1.0 Mg $CO_2$-e/$1000 GDP, respectively.[1] Paddy rice production (sectors PDR) is among the most intensive GHG emitters in all three countries, which can be attributed to the large amounts of methane produced from rice grown under flooded conditions. The GHG content of electricity generation (sector ELY) is particularly high in both China and India because of the inefficiency associated with their coal-dominant electricity generation.

Figure 1 shows the combined GHGs embodied in U.S. imports from China and India of the top 20 sectors with the highest GHG content and corresponding U.S. exports of these sectors. The three highest GHG volumes are embodied in mineral products (sector NMM); chemical, rubber, plastic products (sector CRP); and ferrous metals (sector I_S). Machinery and equipment (sector OME) and electric equipment (sector ELE) have the fourth- and fifth-highest GHG content in bilateral trade, respectively.
The amount of GHG emissions avoided in the U.S. by importing goods from China and India can be readily computed by multiplying the GHG intensity of the U.S. sectors and the related U.S. imports from the two countries together. It turns out that the U.S. avoided 26.1 million Mg $CO_2$-e in 2004 by importing Chinese and Indian products. In other words, if the U.S. had produced these imported products domestically, the GHG emissions in the U.S. would have increased by 26.1 million Mg $CO_2$-e. Furthermore, approximately 57.9 million Mg $CO_2$-e of GHG emissions in China and India were produced during the manufacture of export goods for U.S. consumers. So there are significant environmental

[1] The GHG intensities for sectors in the U.S., China, and India are available upon request.

impacts embodied in U.S.-China and U.S.-India trade: emissions increase in China and India while they simultaneously decrease in the United States.

**Impacts of Border Carbon Adjustments**

The economic and environmental impacts of trade policies imposed on the border, including carbon tariff and export subsidies, are simulated through comparisons between the baseline scenario and various policy scenarios using the GTAP-E model. In accordance with the provisions of the proposed climate legislation, particularly the American Clean Energy and Security Act of 2009 (H.R. 2454), we focus on the energy-intensive trade-exposed (EITE) industries. Essentially, these industries are those that have a relatively large share of energy costs, are more likely to be significantly affected by carbon pricing policy, and are more vulnerable to international competition.

To be eligible for border adjustment policies as EITE industries, a sector must have (i) an energy or GHG intensity of at least 5% and a trade intensity of at least 15%, or (ii) an energy intensity or GHG intensity of at least 20%, regardless of its trade intensity.[2] Following the methodology used by the Environmental Protection Agency (EPA 2009), five aggregated GTAP sectors are considered in this study: chemicals, rubber, and plastic products; pulp, paper, and print; nonmetallic minerals; iron and steel; and nonferrous metals.

First, a baseline scenario is set up to simulate the effects of climate policy alone (without any BCAs). The climate policy is modeled as a domestic carbon tax with an exogenous and constant carbon price, which is imposed on GHG emissions resulting

[2]See EPA 2009 for definitions of the energy, greenhouse gas, and trade intensities and for the method of mapping the six-digit North American Industry Classification System Code to the GTAP sectors.

from fossil fuel consumption in all sectors and commodities through a built-in carbon price mechanism in GTAP-E. An emission price of $15 per ton of $CO_2$-e is imposed, the level of which is representative of near-term prices proposed by various studies. Second, we consider a scenario in which the carbon tariff is applied to the imports of EITE industry products from China and India (Scenario 1). Because GTAP aggregates China and India as one region, we call it China/India in this section. The effects of BCAs are simulated on the combined basis of these two countries, and the GHG intensities are adjusted accordingly. The carbon tariff is calculated as the given carbon price multiplied by the respective GHG intensity in each covered sector. GHG intensity is defined based on the carbon content embodied in imports after accounting for GHG emissions in the production process in exporting countries.

Policy effects of export subsidies are simulated in Scenario 2. By rebating the value of GHG emissions embodied in exports of EITE industries, this policy intends to offset any competitive disadvantages induced by domestic climate policy. The subsidy is implemented by reducing the amount each covered sector paid for domestic carbon taxes, with the reduced amounts calculated using Brown and Gifford's Allowance Distribution Tool (Brown and Gifford 2010). Finally, we combine the policies, carbon tariffs and export subsidies, to investigate their joint effects on competitiveness and carbon leakage in Scenarios 3 and 4. The difference between the last two scenarios is that Scenario 3 uses the GHG intensity of China and India to calculate the carbon tariff while Scenario 4 uses the GHG intensity of U.S. domestic production.

Table 1 compares the effects of different policy scenarios on U.S. domestic production, export prices, and trade flows between the U.S. and China/India, and the

GHG emissions. Compared with no carbon pricing in the case of “business as usual,” in the baseline scenario with a $15 emission price, the trade balance of all U.S. industries is reduced by $1.9 billion, while that of China/India is increased by $76.4 million. Meanwhile, China/India exports $37.1 million more products to the U.S., together with a roughly $304.7 million increase in its industry output. The production contraction associated with a carbon price is about $4.6 billion in the United States. In terms of environmental impact, GHG emissions decline by about 112 million metric tons in the United States, while China/India experiences a 0.6 million metric ton increase in GHG emissions induced by increased industrial production.

In Table 1, the results of all policy scenarios (Scenarios 1-4) represent changes relative to the baseline scenario (i.e., the imposition of a domestic carbon tax) that accompany various BCA policies. Results in Table 1 confirm that the imposition of a carbon tariff on China/India’s EITE products by the U.S. effectively alleviates the impact of carbon pricing on vulnerable domestic industries and slightly raises domestic output of EITE industries. As a result, relative to the baseline, U.S. aggregate imports of the EITE industries from China/India declines by $256.3 million. On the other hand, the export subsidies lead to an increase of $297.9 million in the output of domestic EITE industries.

It is also evident that a combined or full border adjustment policy has bigger impacts than an individual policy. For example, the U.S. trade balance increases by $332.4 million in Scenario 3 compared with increases of $209.3 million in Scenario 1 and $123.2 million in Scenario 2. U.S. industry output increases by $557 million, which is $259.1 million higher than under an export subsidy alone and $297.9 million higher than the output under a carbon tariff. Furthermore, because of the significant difference in

GHG intensities between the U.S. and China/India, the policy impacts are different when different GHG intensities are used to calculate the amount of the carbon tariff. In general, using China/India's GHG intensity leads to more substantial impacts than using that of the U.S. This point is supported by a comparison between Scenarios 3 and 4 in Table 1. In most of the categories, the impacts of a carbon tariff based on the U.S. GHG intensity (Scenario 4) are weaker than those based on China/India's GHG intensity (Scenario 3). But in practice, we lack complete information on the GHG intensity of China/India's imports, and the use of domestic intensity when calculating the carbon tariff could be a reasonable alternative.

In terms of environmental impact, both the carbon tariff and the export subsidy encourage U.S. domestic output and depress industrial production in China/India relative to the baseline. Consequently, they raise U.S. GHG emissions by 0.1 – 6.8 million tons $CO_2$-e and reduce China/India's emissions by 0.4 – 0.7 million tons $CO_2$-e. The carbon leakage concern is largely addressed by these border trade policies. The results also indicate that the U.S. BCA policies may increase global GHG emissions, although the conclusion is constrained by the limited regions we considered in this study.

Results show that the effects of BCAs are generally small, which partly results from the fact that China and India are not large sources of imports in the carbon-intensive sectors considered in this study. But both policy options largely help to mitigate adverse impacts induced by U.S. domestic carbon pricing policy.

## Conclusion

In this study, we examine carbon embodied in bilateral U.S.-China and U.S.-India trade, and the carbon leakage problem under a U.S. carbon policy. With carbon pricing policy in place in the U.S., this cost disadvantage will encourage carbon-intensive production to be shifted to China or India, undermining efforts to cut GHG emissions and contain climate change. Various border carbon adjustment policies, which have been proposed as a solution to this problem, are then examined. This study contributes to the literature on interactions between international trade and the environment. Moreover, our exploration of potential impacts of proposed border adjustments is highly relevant to climate change policy considerations in all countries. One avenue for future research would be to endogenize the emissions price and technological progress, which remained fixed in this study. Keeping track of changes in countries' GHG intensities is another possible direction.

**References**


Ackerman, F., M. Ishikawa, and M. Suga. 2007. The Carbon Content of Japan-US trade. *Energy Policy* 35: 4455-4462.

Antweiler, W., B. Copeland, and M. Taylor. 2001. Is Free Trade Good for the Environment? *American Economic Review* 91: 877-908.

Asselt, H., and T. Brewer. 2010. Addressing Competitiveness and Leakage Concerns in Climate Policy: An Analysis of Border Adjustment Measures in the US and the EU. *Energy Policy* 38: 42-51.

Brown, T., and J. Gifford. 2010. Allowance Distribution Tool. Unpublished. Biobased Industry Center, Iowa State University, January.

Copeland, B., and M. Taylor. 2005. *Trade and Environment: Theory and Evidence.* Princeton, NJ: Princeton University Press.

Dong, Y., and J. Whalley. 2009. How Large Are the Impacts of Carbon Motivated Border Tax Adjustments? NBER Working Paper 15613, National Bureau of Economic Research, Cambridge, MA.

Fischer, C., and A.K. Fox. 2009. Comparing Policies to Combat Emissions Leakage: Border Tax Adjustments Versus Rebates. Working Paper, Resources for the Future, Washington, DC.

Houser, T., R. Bradley, B. Childs, J. Werksman, and R. Heilmayr. 2008. Leveling the Carbon Playing Field: International Competition and US Climate Policy Design. Peterson Institute for International Economics, World Resource Institute, Washington DC, May.

Intergovernmental Panel on Climate Change (IPCC). 2001. *Climate Change 2001*, *IPCC Third Assessment Report.* Cambridge, UK: Cambridge University Press.

Lee, H.L. 2008a. The Combustion-Based $CO_2$ Emissions Data for GTAP Version 7 Data Base. Department of Economics, National Chengchi University.

Lee, H.L. 2008b. An Emission Data Base for Integrated Assessment of Climate Change Policy Using GTAP. GTAP Resource #1143, CTAP $CO_2$ emissions.

Li, Y., and C. Hewitt. 2008. The Effect of Trade between China and the UK on National and Global Carbon Dioxide Emissions. *Energy Policy* 36: 1907-1914.

Lin, B., and C. Sun. 2010. Evaluating Carbon Dioxide Emissions in International Trade of China. *Energy Policy* 38: 613-621.

Lockwood, B., and J. Whalley. 2009. Carbon Motivated Border Tax Adjustments: Old Wine in Green Bottles? NBER Working Paper 14025, National Bureau of Economic Research, Cambridge, MA.

Mattoo, A., A. Subramanian, D. Mensbrugghe, and J. He. 2009. Reconciling Climate Change and Trade Policy. Working Paper 189, Center for Global Development, Washington, DC.

Narayanan, B.G., and T.L. Walmsley. 2008. Global Trade, Assistance, and Production: The GTAP 7 Data Base. Center for Global Trade Analysis, Purdue University.

Organization for Economic Cooperation and Development (OECD). 2010. Linkage between Environmental Policy and Competitiveness. OECD Environment Working Papers, No. 13, OECD, Paris.

Pan, J., J. Phillips, and Y. Chen. 2008. China's Balance of Emissions Embodied in Trade: Approaches to Measurement and Allocating International Responsibility. *Oxford Review of Economic Policy* 24: 354-376.

Rose, S., and H.L. Lee. 2008. Non-$CO_2$ Greenhouse Gas Emissions Data for Climate Change Economic Analysis. GTAP Working Paper No. 43, Global Trade Analysis Project, Purdue University.

Shui, B., and R.C. Harriss. 2006. The Role of $CO_2$ Embodiment in US-China Trade. *Energy Policy* 34: 4063-4068.

U.S. Environmental Protection Agency (EPA). 2009. *The Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries. An Interagency Report Responding to a Request from Senator Bayh, Specter, Stabenow, McCaskill, and Brown.* December. Washington, D.C.: EPA.

Weber, C.L., G.P. Peters, D. Guan, and K. Hubacek. 2008. The Contribution of Chinese Exports to Climate Change. *Energy Policy* 36: 3572-3577.

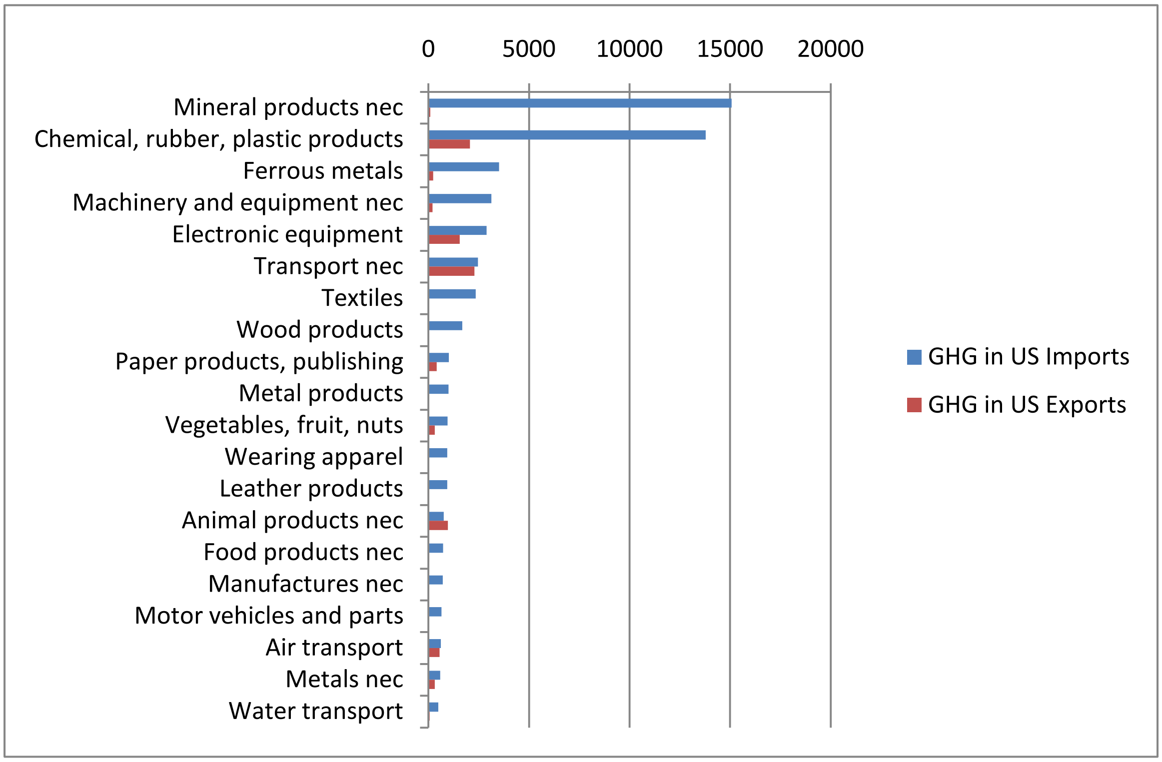


Figure 1. GHG emissions embodied in U.S.-China/India trade for selected sectors (1000 Mg $CO_2$-e).

Table 1. Summary Indicators of Trade Flow and Production of EITE Industries in the U.S. and China/India

| | Baseline | | Scenario 1 | | Scenario 2 | | Scenario 3 | | Scenario 4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Domestic Carbon Tax (No BCAs) All Industries | | Domestic Carbon Tax + Carbon Tariff Using Foreign Intensity | | Domestic Carbon Tax + Export Subsidy | | Domestic Carbon Tax + Carbon Tariff Using Foreign Intensity + Export Subsidy | | Domestic Carbon Tax + Carbon Tariff Using U.S. Intensity + Export Subsidy | |
| | U.S. | China/India | U.S. | China/India | U.S. | China/India | U.S. | China/India | U.S. | China/India |
| Change in trade balance (million $) | -1,913.74 | 76.43 | 209.27 | -437.02 | 123.20 | -4.97 | 332.39 | -441.84 | 59.59 | 125.17 |
| Change in imports (million $) | 696.16 | -25.02 | -256.3 | -78.8 | -44.73 | 1.65 | -300.97 | -77.13 | 30.42 | 25.04 |
| Change in exports between U.S. and China/India (million $) | -59.30 | 37.10 | -7.20 | -533.10 | -19.68 | 5.63 | -27.38 | -536.59 | -17.40 | 151.1 |
| Change in industry output (million $) | -4,595.19 | 304.66 | 259.13 | -597.38 | 297.88 | -19.63 | 557.00 | -616.82 | 222.13 | 157.47 |
| Change in GHG emissions (million tons) | -112.00 | 0.60 | 0.10 | -0.40 | 6.70 | -0.10 | 6.80 | -0.70 | 6.70 | 0.00 |

Notes: (1) Changes in the baseline are relative to the case of "business as usual" and for all industries. (2) Changes in scenarios are relative to the baseline and only for EITE industries.

**Non-discrimination Statement**