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Why carbon border adjustment mechanisms will not save the planet but a climate club and subsidies for transformative green technologies may

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ABSTRACT

We find that both empirical results and economic theory show that carbon border adjustment mechanisms (CBAMs) will be ineffective at meeting global goals for carbon emissions reduction; but CBAMs will be effective at improving the competitiveness of the domestic industries by assuring that imports bear equal costs of carbon pricing. We elaborate two complementary proposals that hold greater promise for meeting climate goals: (i) a Climate Club, where member countries impose a minimum price for carbon emissions at home and a tariff surcharge on all imports from non-member countries; and (ii) a 0.2%-of-GDP subsidy by high-income countries for transformative research designed to make green energy cheaper than fossil fuels. We discuss multiple paths for a Climate Club to be accommodated within the rules of the World Trade Organization and recommend use of the exception clause under GATT Article XX.

1. Introduction

The Paris Agreement on climate change was finalized in December 2015 under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC). Some 196 countries agreed to submit Nationally Determined Contributions (NDCs), with the collective goal of limiting the increase in global temperatures to less than two degrees Celsius above the pre-industrial level. The NDCs under the Paris Agreement, however, are voluntary, non-binding pledges for emission-reduction that terminate in 2030. The United Nations reported in 2022 that, even if all pledges are fully realized, "we are still nowhere near the scale and pace of emission reductions required."[1]

There is a group of countries which, in the hope of significantly reducing global greenhouse gas (GHG) emissions, tax or price GHG emissions in their home markets. These countries, which we refer to as "coalition" countries, include the European Union (EU), the United Kingdom (UK) and the countries of the European Free Trade Area (EFTA). We observe some of the highest prices in the world for carbon-emission permits in these coalition countries.[2] In contrast, we call the set of countries not pricing GHG emissions, or having lax regulations, "non-coalition" countries. (The countries included in the coalition in this paper will vary somewhat according to the model applied.)

The benefits of a clean atmosphere are a global public good from which no country can be excluded, but the emissions of all countries contribute to the accumulated carbon emissions in the atmosphere. Since reducing emissions is costly, self-interested countries prefer to "free ride" on the abatement efforts of other countries. Overcoming free riding by autonomous governments is the fundamental challenge for an effective cooperative agreement on climate change.

Economic theory indicates there is a "competitive" effect whereby

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[1] See United Nations Climate Change (2022), "Climate Plans Remain Insufficient: More Ambitious Actions Needed Now," October 26. Available at: https://unfccc.int/news/climate-plans-remain-insufficient-more-ambitious-action-needed-now. The report shows that the updated commitments under the Paris Agreement will result in emissions in 2030 that will exceed 2010 levels by 10.6%. However, the 2018 report of the UN's Intergovernmental Panel on Climate Change indicates that CO_2 emissions need to be cut 45% by 2030, compared to 2010 levels.

[2] The price of a permit to emit one ton of carbon dioxide equivalent under the Emissions Trading System of the EU ranged between 56 and 97 euros in 2022. See: https://tradingeconomics.com/commodity/carbon

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firms producing carbon-intensive products in the coalition countries will see their costs of production increase and lose competitiveness against imports from firms in countries with lax climate-regulation policies. Coalition countries fear that this competitive disadvantage imposes larger costs on them, makes carbon-emissions regulation politically difficult, and reduces the effectiveness of their GHG-abatement policies, since emissions in non-coalition countries may increase due to "carbon leakage."[3] These fears led to the provisional agreement on December 12, 2022 by negotiators for the European Council and the European Parliament for a carbon border adjustment mechanism (CBAM), which is the first tax on embedded carbon at an international border. Since countries that adopt carbon pricing will see a reduction of the CBAM tax on their exports to the EU, there is a hope expressed by some, including EU President von der Leyen,[4] that a CBAM will significantly reduce carbon emissions and encourage carbon pricing in countries facing a CBAM on their exports.

In this paper we address the following research questions: 1) What are the likely key effects of the CBAM? 2) Will it reduce carbon leakage and induce non-coalition countries to significantly reduce their carbon emissions to meet global emissions goals? 3) How can we construct a cooperative international agreement for climate objectives that successfully addresses the free-rider problem and can be accommodated within the rules of the World Trade Organization? 4) Are subsidies needed for technological solutions to GHG emissions and, if so, what kind?

We find that both economic theory and the empirical results show that carbon border adjustment mechanisms will be ineffective at meeting global goals for reducing carbon emissions. We find that the CBAMs should be successful at neutralizing the competitive advantage of imports from countries with weak carbon regulations[5]; and the EU CBAM will thereby improve the competitiveness of EU and other coalition firms in industries that are both energy-intensive and trade-intensive. For countries considering imposing or increasing economy-wide carbon pricing, a CBAM should contribute to the political acceptance of carbon pricing.

We offer two proposals designed to meet the challenge of climate change. First, we propose a Climate Club that builds on the proposal of Nordhaus (2015, 2018). Results from large numbers of real-world systems, laboratory experiments and game-theory studies of common-resource situations all show that *reciprocity,* as long as it is monitored and enforced, is the fundamental component of successful cooperation in common-resource situations. The lack of reciprocity is a key reason that the Kyoto Protocol collapsed and that the Paris Agreement is not meeting its objectives. Membership of a country in the Climate Club would depend on the member imposing a minimum, nationwide price of carbon across all sectors while non-members would be subject to a uniform import-tariff surcharge on all goods imported into member countries. The Climate Club contains reciprocity of commitments and an enforcement mechanism, which is why we view it as our best hope for overcoming the free-rider problem inherent in an international climate agreement among autonomous governments. Our second proposal is for a 0.2%-of-GDP subsidy by high-income countries for basic research on transformative technologies aimed at making green energy cheaper than fossil fuels.

Since the penalty tariff on non-members would appear to violate both the most-favored-nation (MFN) principle and the maximum-bound-tariff commitments of Climate Club members (Articles I and II of GATT (1947)), we discuss three possible approaches for Climate Club members to act within the rules of the World Trade Organization (WTO) and explain why we recommend immediate use of the Exception clause in Article XX of the GATT to justify the Climate Club within the WTO.

Since the Russian Federation is the largest exporter of emission-intensive products to Europe, the world's largest exporter of fossil fuels, and the fourth largest emitter of GHGs in the world, we investigate the case of the Russian Federation in detail. Given the experience of post-World War II Germany,[6] we expect that the Russian Federation would be reintegrated into the world trading environment at some point in the future. The models we review estimate that the proposed CBAM of the EU (which the UK and EFTA countries also join) would reduce Russian GHG emissions by a modest 1.6%. In contrast, Russian domestic carbon pricing would reduce its GHG emissions by 38%.

In section 2, we explain what the EU CBAM is and why carbon border adjustment mechanisms are inefficient at meeting global carbon-emissions objectives. In section 3, we summarize estimates from 15 modeling teams regarding the impact of carbon border adjustment mechanisms on GHG emissions abatement in non-coalition countries. In section 4 we look in detail at the case of Russia. In section 5, we elaborate two proposals to achieve global climate goals: a Climate Club and subsidies for transformative green technology. We discuss how the Climate Club may be accommodated within the rules of the WTO in section 6, and present conclusions in section 7.

2. A CBAM allows domestic industries to compete equally with imports but is inefficient at reducing global carbon emissions

2.1. What is the CBAM?

The CBAM of the European Union is the first proposed tax on the carbon-dioxide-equivalent (CO_2e) emissions embodied in the imports of designated products. While crediting imports for any carbon taxes paid in their home country, it is to be designed to tax imports at a rate equivalent to the price EU firms must pay for their GHG emissions under the EU's Emissions Trading System. The CBAM should thereby neutralize the advantage imports have in energy-intensive and trade-intensive industries, allowing such industries in the EU to compete on an equal footing with imports from countries that have weak regulations on carbon emissions.

The EU's CBAM proposal is in response to the resolution of the European Parliament adopted in March 2021 advocating the introduction of a World Trade Organization (WTO)-compatible carbon border adjustment mechanism. On December 12, 2022, negotiators for the European Council and the European Parliament reached agreement on a

[3] Further, firms in emission-intensive industries in coalition countries may relocate to countries with less stringent GHG emission regulations, again reducing the effectiveness of efforts by coalition countries to reduce GHG emissions. Finally, coalition country GHG regulation will lower the price of fossil fuels in non-coalition countries, thereby stimulating demand for fossil fuels in non-coalition countries.

[4] In her September 2020 State of the Union address, the EU President stated, "Carbon must have its price – because nature cannot pay the price anymore. This Carbon Border Adjustment Mechanism should motivate foreign producers and EU importers to reduce their carbon emissions." The Report of the European Parliament Research Services (Titievskaia, 2022, p.2) states: "The CBAM… could also encourage partner countries to adopt carbon pricing that tests the prediction of a Brussels effect." And the European Commission (2021, p.3) states: "the EU will engage with third countries… [to] explore possibilities for concluding agreements to take into account their carbon pricing mechanism."

[5] The most significant emitters of carbon dioxide in the non-coalition are listed in Table 4 as non-Annex I countries, headed by China, India, Russia, Brazil, and Indonesia.

[6] Germany was not invited to become a founding member of the International Monetary Fund or the World Bank, both of which were established on December 27, 1945; but the Federal Republic of Germany joined both institutions on August 14, 1952. Similarly, the Federal Republic of Germany was not a member of the GATT when it was founded on January 1, 1948 but became a member on October 1, 1951.

"provisional" CBAM that is to become fully operational on January 1, 2026, with a transition period beginning October 1, 2023.[7] The agreement needs to be adopted by both institutions and confirmed by the ambassadors of the member states before it becomes law.

The products negotiated in the agreement of December 12, 2022, are listed as Phase-I products in Table 1. The Chahim Report (2021)[8] and European Commission (2021) indicated an intention to widen the range of covered products. In Table 1, we (unofficially) list the products likely to be part of Phase II. Our Phase-II list is consistent with the list in the World Bank-Higher School of Economics report (Makarov et al., 2021) and includes plastics and chemicals, which were proposed for Phase I in the Chahim Report (2021).

2.2. Free allowances and carbon leakage

2.2.1. Free allowances

Free allowances refers to the free provision of emissions certificates to European firms in industries that are energy-intensive and trade-intensive. The EU has provided free allowances to these industries to help them avoid a competitive disadvantage against imports. A problem with free allowances is that they diminish the incentive of the energy-intensive and trade-intensive industries to reduce their carbon emissions. An important objective of the EU in introducing the CBAM is to allow its energy-intensive and trade-intensive industries to compete on an equal footing with imports, and thereby allow the EU to eliminate "free allowances" of CO_2 permits to these industries. The negotiated agreement before the European Parliament has a phased schedule which progressively eliminates free allowances in the Phase-I sectors by 2034.

2.2.2. Carbon leakage

The CBAM is also intended to combat "carbon leakage" from the Emissions Trading System of the EU. Carbon leakage refers to a situation where CO_2 pricing or regulations in one country or region induce an increase in CO_2 emissions in regions with weak regulation of CO_2 emissions, blunting the global impact of emission-reduction policies. We assess the impact of the CBAM on carbon leakage in sections 3 and 4.

2.3. Why a CBAM is inefficient at reducing global carbon emissions

2.3.1. A CBAM does not address most GHG emissions

Since climate change is a global problem, we are concerned with global GHG emissions regardless of source, not only the GHG emissions embedded in imports – or more narrowly, imports to the EU and like-minded countries. This means we need to tax all GHG emissions regardless of their source. This is a special case of a theorem of Bhagwati and Ramaswami (1963), who show that if we want to efficiently control an externality or address a non-economic objective, an efficient tax or subsidy must be applied at the the point at which the distortion occurs. A tax focused only on imports, and even more narrowly on imports to the EU and its coalition, misses the vast majority of GHG emissions in the world.

For example, if we take the period 2015–2019, Russia supplied the largest share of imports to the EU 27 of products covered by Phase I of the EU's CBAM.[9] For the likely products covered by the CBAM in Phase I or Phase II, Table 1, column 12 shows that Russia's exports to the EU in 2021 accounted for between 0.1% of Russian output of cement, to a high of 21% of sector ouput of non-ferrous metals (nec). Russian exports to the EU of all goods account for 13 % of the value of Russia's goods output and 11 % of the value of its non-fossil-fuel goods output. Clearly, the CBAM has virtually no impact on GHG emissions from the Russian cement sector and, despite the fact that Russia provided the largest share of the EU's product imports, the CBAM impacts only a minority of Russia's manufacturing sector more broadly.

2.3.2. Carbon emissions embedded in intermediates are difficult to monitor and likely to be excluded by a CBAM

The Chahim Report supports including intermediates that are components of imported goods in the CBAM. Despite the fact that the majority of "imported" GHG emissions is embedded in intermediate goods (Böhringer et al., 2022, p.24), as currently proposed, the CBAM of the EU does not envisage taxing embedded carbon emissions, except for electricity inputs in goods. To illustrate, the components for automobiles are typically produced in many locations, often by firms that are independent of the automobile producer, and sent to a plant for final assembly. If autos were included in a CBAM, the proposed CBAM of the EU on an imported automobile would only tax the final assembly process of the automobile and ignore the carbon embedded in the components. Böhringer et al. (2022) note that it is extremely difficult to monitor and calculate emissions embedded in the components of an imported good.

2.3.3. Default values remove the incentives to reduce carbon emissions

To obtain a reduction or waiver of the CBAM tax on their exports to the EU, non-EU firms will have the difficult task of providing third-party verifiable data on the carbon content of their exports to the EU. Provision of such verifiable data may be possible (although difficult) for direct emissions but requiring these data for indirect emissions probably will be prohibitively expensive. As a result, the CBAM will likely have default values based on industry or technology-specific measures of embodied carbon. Default values for the carbon efficiency of the CBAM, however, reduce the incentive for firms that export to the EU to reduce their emissions, diminishing the CBAM's effectiveness in reducing carbon leakage. To address this, the EU could assist exporters in their efforts to provide verifiable data on the carbon content of their exports to the EU.

2.3.4. Some market reactions to the CBAM will weaken GHG abatement

Although there are market adaptations to the CBAM that will result in fewer global CO_2e emissions, some market reactions will weaken GHG abatement. Two of these latter impacts are: (i) firms will shift sales to markets that do not regulate carbon emissions or have lax regulations; and (ii) lower prices of carbon-intensive products in non-coalition countries will have the unintended effect of increasing consumption of carbon-intensive products in those countries (Balistreri et al., 2019). The modeling assessments we discuss below endogenously assess the net impact of these various market adjustments.

3. How much will a CBAM reduce GHG emissions?

3.1. Methodology of the energy modeling forum study

Under the auspices of the Energy Modeling Forum (EMF), twelve international computable general equilibrium (CGE) modeling groups assessed the impact of a carbon border adjustment mechanism with identical policy experiments and identical GTAP7.1 datasets.[10] The results of the EMF study are summarized by Böhringer et al. (2012). In this section we draw some new inferences from their results for the role of a

[7] https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-carbon-border-adjustment-mechanism

[8] The Chahim Report (2021) is the report of the Committee on the Environment, Public Health and Food Safety of the European Parliament. On December 21, 2021, the Committee submitted a draft resolution on the CBAM to the European Parliament which strengthened several respects the CBAM recommendations of the European Commission (2021).

[9] https://resourcetrade.earth/publications/which-countries-are-most-exposed-to-the-eus-proposed-carbon-tariffs

[10] The Global Trade Analysis Project (GTAP) is an international consortium of researchers conducting quantitative analysis of international economic policy. A primary function of GTAP is to produce international datasets available to all members.

Table 1
Russian exports in 2021 of likely CBAM products.

	Exports in millions of		Sales in Russia	Sector Exports as a % of		% of the Sector's Exports by Region				Exports % of Sector Output	
	US Dollars	Rubles	Millions of Rubles	Total exports	Russian GDP	EU + EFTA	CIS	APEC	ROW	All exports	to EU + EFTA
Phase I sectors											
Aluminum	8426	620,823	816,662	1.5%	0.5%	31%	9%	40%	20%	43%	13%
Cement	77	5661	274,830	0.0%	0.0%	4%	96%	0%	0%	2%	0%
Electricity	1327	97,498	2,654,357	0.2%	0.1%	72%	12%	14%	3%	4%	3%
Fertilizers	10,844	797,672	833,944	2.0%	0.6%	30%	8%	19%	43%	49%	15%
Iron and Steel	28,682	2,112,255	4,911,045	5.3%	1.6%	28%	23%	27%	22%	30%	8%
Hydrogen	0	17	36,920	0.0%	0.0%	0%	100%	0%	0%	0%	0%
Phase II sectors											
Chemicals	3450	254,146	601,976	0.6%	0.2%	54%	17%	14%	15%	30%	16%
Plastics	6171	454,494	1,992,365	1.1%	0.3%	23%	49%	13%	14%	19%	4%
Non-ferrous metals, nec	2636	194,910	603,105	0.5%	0.1%	86%	1%	12%	2%	24%	21%
Non-metallic minerals	3281	241,129	1,647,511	0.6%	0.2%	30%	41%	2%	27%	13%	4%
Other extractive sectors	8209	604,668	970,899	1.5%	0.5%	42%	4%	18%	37%	38%	16%
Petroleum & coal products	73,125	5,384,833	9,896,942	13.4%	4.1%	54%	7%	20%	20%	35%	19%
Total all goods less oil, gas and coal	355,693	26,178,980	63,010,068	65%	20%	38%	16%	19%	27%	29%	11%
Total all goods	491,580	36,166,976	71,489,200	90%	28%	39%	13%	27%	21%	34%	13%
Total all goods and services	546,613	40,219,769	230,482,295	100%	31%	39%	14%	26%	21%	15%	6%

Source: Trade data from the Federal Customs Service of Russia (http://stat.customs.gov.ru/unload); Rosstat for GDP at: https://rosstat.gov.ru/storage/mediabank/VVP_kvartal_s_1995.xls) and sectors revenues (https://fedstat.ru/indicator/57710. Accessed March 12, 2023.

CBAM in meeting global GHG emission targets.

All the modeling teams made the following assumptions: Coalition countries are the Annex-I Parties to the UNFCCC minus Russia. (See Table 4 for the list of such countries.) Two policy scenarios are compared to a "Business-as-Usual" scenario. In Policy Scenario 1, all countries in the coalition target a global reduction of GHG emissions equal to 20 % of the GHG emissions of the coalition. Emissions permits may be traded throughout all coalition countries. To meet the target for global reductions of GHG emissions, coalition countries must reduce their own emissions to offset carbon leakage in the non-coalition.[11] Policy Scenario 2 has the identical objective of a global GHG emission reduction of 20 % compared to the initial emissions of the coalition, but all the coalition countries combine unilateral emissions abatement with a CBAM. The CBAM taxes are imposed on embodied GHG emissions on imports of energy-intensive and trade-intensive imports[12] from non-coalition countries. Embedded GHG emissions from the use of electricity are accounted for in the models but are ignored for other intermediate goods. Emissions taxes paid by firms in coalition countries are rebated on their exports. The CBAM taxes are retained by the coalition countries.

Eleven of these twelve modeling teams exclusively employed the Armington structure. Balistreri and Rutherford (2012), however, developed a "heterogeneous-firms" model that is consistent with the extensive empirical evidence on the diversity or heterogeneous nature of firms in an industry.[13] The results of this EMF study, as well as Balistreri et al. (2018), show that, compared with models consistent with the evidence of firm heterogeneity, Armington models have two important differences with respect to unilateral GHG emissions abatement policies of the coalition: (i) Armington models underestimate carbon leakage; and (ii) in response to coalition GHG abatement policies, they overestimate burden-sharing in the non-coalition.[14] In Table 2, we report results for the mean estimate of the twelve teams for the coalition countries, non-coalition countries, and for Russia, China and India. Since we believe the results from the heterogeneous-firms model is likely to be more accurate, we separately report the results from that model. We explain the reasons for these different model estimates in Tarr et al. (2022, appendix B).

3.2. *Carbon leakage results*

3.2.1. *Carbon leakage in response to unilateral coalition GHG abatement*

In Policy Scenario 1, all the models show carbon leakage from unilateral abatement with a mean estimate of 11.8% and a range from 5 % to 19.1%. The largest estimate of carbon leakage is from the heterogeneous-firms model. The mean estimate implies that, for every 100 tons of GHG emissions that the coalition reduces, the non-coalition countries increase their GHG emissions by 11.8 tons.

3.2.2. *A CBAM is insufficient to offset the carbon leakage effect of coalition abatement*

The mean estimate of the models is that the CBAM reduces carbon leakage in the non-coalition from 11.8% to 7.7%. Despite the application of a CBAM, carbon leakage remains positive for the non-coalition countries collectively. All 12 models in the EMF study estimate that the combination of unilateral GHG emission abatement policies of the coalition and a CBAM induce the non-coalition countries to increase their GHG emissions. While the results show that a CBAM will reduce carbon leakage and help to maintain competitiveness of energy- and trade-intensive industries in the coalition, a CBAM is insufficient to offset the carbon-leakage effect of the coalition's unilateral abatement policies. As the emission-abatement policies of the coalition are strengthened over time, these results suggest that carbon leakage may

[11] Carbon leakage is defined as the increase in emissions in non-coalition countries divided by (the absolute value of) the decrease in emissions within the coalition.

[12] All models incorporate all the energy and trade intensive sectors in the GTAP database: chemicals, non-metallic minerals, iron and steel, non-ferrous metals and refined oil products. They also all include the following energy sectors: coal, natural gas, crude oil and electricity.

[13] Armington models assume all firms in each country are perfectly competitive and have identical cost and production structures. Heterogeneous-firms models assume imperfect competition among firms in an industry with diverse cost and production structures.

[14] This is due to significantly larger estimates of terms-of-trade effects in Armington models. See Balistreri and Tarr (2022) and Caliendo and Feenstra (2022).

Table 2
Impact of coalition climate change policies: comparison to "Business as Usual". Results from 12 modeling teams of the energy modeling forum study.

	1	2	3	4
	11 Armington Models + 1[a]		Melitz Model	
	EMF Mean Estimate			
	Coalition Unilateral Climate Polices[b]			
	No CBAM	Plus CBAM	No CBAM	Plus CBAM
Welfare/GDP				
Coalition countries	−0.4	−0.31	−0.65	−0.04
Non-coalition aggregate of which:	**−0.14**	−0.30	**0.25**	−1.9
Russia	−1.09	−1.42	−0.93	−6.0
China	0.01	−0.01	0.26	−0.79
India	0.21	0.20	0.37	0.15
Carbon Leakage				
Non-coalition aggregate of which:	**11.8**	**7.7**	**19.1**	**9.5**
Russia	1.6[c]	0.2[c]	3.3	−0.6
China	2.4[c]	1.9[c]	2.6	1.5
India	1.0[c]	0.8[c]	0.9	0.7

Source: Böhringer et al. (2012) and Balistreri and Rutherford (2012).
[a] The mean is over 12 models, where the estimates of the 12th model is the heterogeneous-firms model of Balistreri and Rutherford (2012).
[b] **Scenario Definitions: Business-as-Usual scenario:** the historical situation in 2004; **Coalition Unilateral Climate Policies scenario:** a coalition of Annex I, Parties to the UNFCCC except Russia employ unilateral emissions abatement policy to reduce GHG emissions by 20% of their initial emissions; and (ii) **Plus CBA scenario:** in addition, the coalition adopts CBAM taxes on non-coalition countries and emissions taxes are rebated on exports.
[c] Carbon leakage is defined as the increase in CO_2 emissions divided by the absolute value of the reduction in coalition CO_2 emissions. These estimates are from Balistreri and Rutherford (2012, Table 5), since EMF mean estimates are unavailable.

even increase. Importantly, since global emission targets require emission reductions by non-coalition countries, not simply the absence of carbon leakage, additional measures are needed to achieve global emission targets.

3.3. Welfare effects

Regarding burden sharing by the non-coalition of GHG unilateral emission policy of the coalition (Policy Scenario 1), the 12 modeling teams mean estimate for GDP change[15] of the *non*-coalition countries is *negative* 0.14%. (See Böhringer et al., 2012, fig. 6.) Nine of the eleven Armington models show negative GDP changes for an aggregate of the non-coalition countries, and the remaining two Armington models estimate positive but close-to-zero change in GDP. Contrary to the theory and intuition that free riding will result in non-coalition countries gaining from the GHG emission policies of the coalition, these Armington models typically find that non-coalition countries in aggregate lose (or do not gain in some cases) from coalition abatement policies, even without a CBAM. That is, without a CBAM, Armington models typically find burden-sharing of the costs of abatement by non-coalition countries. On the other hand, consistent with theory, the heterogeneous-firms model finds a gain for the non-coalition countries of 0.25% of GDP.

Regarding burden sharing from the impact of a CBAM by the coalition (Policy Scenario 2), the mean estimate of the 12 models shows the expected result that, compared with unilateral abatement policies, the CBAM increases the GDP of the coalition and decreases the GDP of the non-coalition. In the heterogeneous-firms model, the CBAM induces a sign change whereby the non-coalition is estimated to lose 1.9% of GDP. All 12 models show losses for the non-coalition from the combined effects of unilateral GHG emissions abatement by the coalition and a CBAM.

3.4. Will the CBAM induce carbon pricing?

There are some who hope that the CBAM of the EU will provide an incentive to its trading partners to price their domestic CO_2e emissions. A non-coalition country that only considers its own national income, ignoring global emissions and welfare, faces a trade-off in its decision-making between the net costs of its abatement efforts versus the costs of the CBAM. It would choose to undertake abatement if the costs of abatement (net of reduced damages) are less than the costs of incurring the CBAM tax penalties.

Nordhaus (2015, p. 1348) estimates that the CBAM costs are too low to induce a significant number of non-coalition countries to take on the costs of GHG abatement. Similarly, the model results of Bekkers and Cariola (2022, p. 33) indicate that, for countries that are not regulating carbon emissions, the potential of a CBAM to induce them to take climate change measures is very limited. Böhringer et al. (2016, p.45) assume that Europe (EU-27 plus EFTA) employs carbon pricing and imposes a CBAM on outside countries if and only if they do not price carbon. In their Nash equilibrium, they find that a European CBAM will only induce carbon pricing in China and Russia, while all countries in the rest of the world, except India, retaliate against Europe with countervailing duties.[16] They estimate that even the United States, Japan and the rest of Annex-I countries free ride on the abatement efforts of Europe and use countervailing duties against the European CBAM.

Collectively, these studies suggest that the strategic value of a CBAM to induce carbon pricing is minimal. A stronger penalty mechanism for the lack of substantial abatement efforts appears necessary to address the free-rider problem.

4. Impact of the CBAM of the EU on Russia with and without Russian domestic GHG abatement policy

4.1. Political economy of Russian climate policy

In 2021, there was a significant change in Russian official policy and declarations with respect to climate change. In his April 2021 address to the Federal Assembly, President Putin for the first time declared that addressing climate change was a priority for Russia. This reflects an evolution of the President's views from denying climate change or the human contribution to it, to acknowledging its possibility and the threat climate change poses for Russia. He stated: "we must minimize the impact we have."[17] In July 2021, Putin signed the law limiting greenhouse gas emissions, which, among other things, requires monitoring and data collection of GHG emissions.[18] In October 2021, the Russian Government adopted a long-term climate strategy (the "Strategy")

[15] The authors indicate that the welfare changes are close to the GDP changes.

[16] Böhringer et al. (2016) also assess the CBAM impact in a model in which they *assume* that all Annex-I countries less Russia price carbon emissions. We regard this scenario to be of limited policy relevance since it does not address the free-rider problem among Annex-I countries. The free-rider problem was evident when the United States and Australia failed to ratify the Kyoto Protocol, and Japan, Canada and Russia withdrew from the agreement.

[17] See Moscow Times (2021), "Putin's Views on Climate Change Evolved Over the Years," updated September 7. Available at: https://www.themoscowtimes.com/2021/07/01/skepticism-to-acceptance-how-putins-views-on-climate-change-evolved-over-the-years-a74391

[18] Federal Law No. 296-FZ of 02.07.2021 "On Limiting Greenhouse Gas Emissions. Available at:http://publication.pravo.gov.ru/Document/View/0001202107020031.

which targets carbon neutrality by 2060.[19] The Strategy recognizes climate change as a significant problem for Russia, and section IV provides a long list of measures to reduce carbon emissions.[20] In 2022, as a step toward implementing the Strategy, the Government introduced carbon pricing in Sakhalin oblast as an experiment for nationwide carbon pricing.

Despite these steps, many in the international community continue to view Russia as a conservative producer of fossil fuels and a climate-change skeptic.[21] Skepticism begins with the recognition that, as the world's largest exporter of fossil fuels, Russia stands to lose wealth compared to most countries from the decline in demand for fossil fuels. Its electricity is generated with almost no solar or wind. Russia's Paris commitment to reduce its carbon emissions by 30% relative to 1990 has been met without taking steps toward carbon-emission reductions, mainly due to the decline in industrial output after the fall of the Soviet Union. Until the international community sees Russia implement carbon-reduction measures, it will likely remain skeptical of the expanded list of measures in the Strategy. Russia counters these criticisms by noting that about 35% of its electricity is generated without emitting GHGs, equally divided between hydroelectric and nuclear power facilities. Furthermore, Russia believes that its effort to expand forests to capture carbon should be included in international carbon accounting. Russia also notes that many countries have not fulfilled their Paris commitments and that the Russian Government would like to see widespread fulfillment by others before Russia strengthens its own international commitments.[22]

We explain in the next section that the designs of the Kyoto and Paris agreements were flawed for the objective of achieving international cooperation on climate change. The reciprocity of commitments that Russia demands is *necessary* for an *effective* international cooperative agreement on climate change. Although the momentum Russia had in 2021 for action on climate change was lost in 2022, assuming an end to the military hostilities in Ukraine, model estimates (Nordhaus (2015) and Bekkers and Cariola, 2022) indicate that Russia would implement carbon pricing *at a price that would address the global externality* under a well-designed international agreement that contains reciprocity. This is our view as well.

4.2. Modeling methodology

As part of a joint report of the World Bank and the Higher School of Economics of Moscow entitled *Russia and the Green Transition*, Makarov et al. (2021, section 2) estimate the impact of the proposed CBAM of the European Union on the Russian Federation, with and without domestic policy in Russia to reduce GHG emissions. These authors employ the Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) model available from the GTAP consortium.[23] The model is a recursive, dynamic, multi-region, multi-sector computable general equilibrium (CGE) model in the Armington style. Their model first projects a baseline (or Reference scenario) for the development of the economy of the Russian Federation between 2014 and 2035 in which all countries implement their commitments under the Paris climate agreement. It then progressively imposes the CBAM over time (consistent with European Commission, 2021) and compares the evolution of the Russian economy to this baseline over the period 2014 to 2035. They evaluate the outcome: (i) under the assumption that Russia takes no additional policy action; and (ii) under the assumption that Russia introduces a generalized carbon tax at the same level as the European Union.

Makarov et al., 2021) assume the CBAM will be applied (in phases) to direct emissions in steel, cement, electricity, fertilizers, chemicals, coking coal, asphalt bitumen, petroleum products, iron ore, aluminum, glass, and non-ferrous metals and on indirect emissions (those embedded in intermediate use) from electricity. Except for one scenario, they assume that the CBAM is not applied to fossil fuels (oil, gas, and coal).[24] In all their scenarios, they assume that the CBAM will be gradually imposed throughout the EU, the UK and EFTA[25] countries. (In this section, these are the "coalition" countries).

In Table 3, we summarize results from two scenarios from Makarov et al. (2021). In the first scenario, no policy action is taken by Russia regarding domestic carbon pricing beyond measures taken to achieve their Paris climate agreement NDC. In the second scenario, Russia is assumed to impose and progressively increase carbon taxes or prices until they reach the level of the EU price of carbon emissions.[26]

4.3. GHG emissions of Russia

The most dramatic result of these estimates is the difference in the estimates of the reduction of GHG emissions depending on whether Russia imposes domestic pricing of such emissions. Without domestic pricing of GHG emissions, the CBAM is estimated to reduce such emissions in Russia by only 1.6% in 2035. With domestic carbon pricing, however, Russian GHG emissions are estimated to fall by 38% by 2035. The dramatically larger impact on GHG emissions in Russia of domestic carbon pricing compared to the CBAM is explained by the fact that the CBAM only impacts a small share of Russia's output, while domestic carbon pricing impacts all of its output.

4.4. Russian exports: impact of the CBAM

4.4.1. Russia's total exports and exports of CBAM-targeted products

Table 3 shows that the imposition of the CBAM will induce coalition importers to reduce real imports from Russia by about US$ 19 billion (in 2014 prices) by 2035. However, the adverse export impact on Russia of the loss of these exports will be mitigated by an increase of US$ 11 billion in aggregate exports to other regions, for a net loss of aggregate exports of US$ 8 billion annually by 2035, a figure equivalent to about 2 % of Russia's total exports in 2019.

Despite the rather modest impact of the CBAM on Russia's total exports, Table 3 shows that Russia's exports of CBAM-targeted products to coalition countries are estimated to fall by 14 to 63%, depending on the product category (chemicals, more than 60%; mineral products, 30–40%; electricity, almost 30%; ferrous metals, about 20%; and petroleum and coal products, about 20%). These estimates indicate that the CBAM makes the import of carbon-intensive products more expensive in the coalition countries and thereby increases the competitiveness and output of these products in coalition countries, i.e., the CBAM allows these industries in the coalition to compete on an equal footing with imports. Then the CBAM is likely to allow the European Union to be successful in its important objective of eliminating free allowances of

[19] See: Ministry of Energy of the Russian Federation (2021).
[20] See: Order of the Government of the Russian Federation of 29.10.2021 N 3052-р. Available at:http://publication.pravo.gov.ru/Document/View/0001202111010022.
[21] For example, the Climate Action Tracker website rates the efforts of the Russian Federation as "critically insufficient." See: https://climateactiontracker.org/countries/russian-federation/. For Russia's NDC under the Paris agreement see: https://unfccc.int/sites/default/files/NDC/2022-06/NDC_RF_eng.pdf
[22] See also Oshchepkov (2021) for an assessment of accomplishments and remaining challenges for Russia in meeting climate objectives; and Davydova (2022) for an elaboration of Russia's responses to the criticism of its climate-change policies.
[23] The model is documented in Van der Mensbrugghe (2019).
[24] In one scenario they assume that the CBAM is also applied on the CO_2 from the production and transportation of fossil fuel, not the carbon content of the fuel itself.
[25] The EFTA countries are Iceland, Liechtenstein, Norway and Switzerland.
[26] We discuss the scenario in which the change in the tax revenue of the Russian Government is transferred to the households as a lump sum.

Table 3
Impact of a European[a] CBAM on Russia, with and without Russian Carbon Pricing. Data are Percentage Change in 2035 with CBAM imposed compared to a "Business-as-Usual" Reference Scenario[b].

	1	2	3	4	5	6
	EU + UK + EFTA Impose the CBAM			EU + UK + EFTA Impose the CBAM		
Impact on Russian:		Russia Business as Usual[c]			Russia Imposes Carbon Pricing[d]	
GHG emissions		−1.6%			−38%	
GDP		−0.1%			−0.3%	
Real consumption		−0.3%			−0.5%	
Exports and Output	**Exports in 2035**		**Output**	**Exports in 2035**		**Output**
	to Europe	**to All Countries**		**to Europe**	**to All Countries**	
Aggregate	-US$ 19 billion[e]	-US$ 8 billion		NA[f]	1%	
Chemical products	−63%	−20%	−5%	−33%	−33%	−14%
Mineral products	−35%	−19%	−3%	−20%	−19%	2%
Electricity	−28%	−13%	−1%	−26%	−25%	−18%
Petroleum and Coal *products*	−22%	−10%	−5%	−2%	−6%	−9%
Ferrous Metals	−18%	−2%	−1%	−5%	−10%	−5%
Metals (other)	−14%	−6%	1%	4%	2%	10%
Oil	8%	10%	1%	NA[f]	17%	2%
Gas	4%	1%	−1%	NA[f]	20%	−59%
Coal	7%	6%	1%	NA	−3%	−17%

Source: Makarov et al. (2021, pp. 17–31 and Annex D). Sector results in columns 2, 3, 5 and 6 are based on updated results provided in private communication with Hasan Dudu on May 16, 2022.
[a] European countries that apply the CBAM in these scenarios are the European Union, the United Kingdom and the EFTA countries.
[b] In the Business-as-Usual or Reference Scenario there is no CBAM, but Russia, the EU and other countries limit their GHG emissions according to their Nationally Determined Contributions (NDCs) under the Paris Climate Agreement.
[c] Makarov et al. (2021) call this scenario "Carbon Price / CBAM Scope 1,2 (EU)."
[d] Revenue from carbon pricing is transferred to households lump sum. Makarov et al. (2021) call this scenario "Russia Carbon Price with recycling to HH."
[e] Dollar values are reported in 2014 constant dollars.
[f] NA means not available in the source.

CO_2 permits to these industries. The drop in Russian exports to the coalition countries of CBAM products is much stronger than its total exports of these products, due to a significant reorientation of Russian exports of CBAM products toward markets that do not tax the embedded carbon in these exports.

4.4.2. *Russia's fossil fuel exports to Europe*

Since the CBAM products are energy intensive, the increase in their production in the coalition countries increases the demand for fossil fuels in these countries. Table 3 shows that *the CBAM alone* will induce an estimated increase in Russian exports of oil, gas and coal to the coalition region. Compared with the baseline, the model estimates that in the 2030–2035 period Russia increases coal exports to the coalition region by 7%, oil exports by 8% and gas exports by 4%.

In the long run, however, as the world transitions away from fossil fuels, these estimates for Russian fossil fuel exports are reversed. Makarov et al. (2020) estimate that fossil fuel exports to Europe, especially coal, will decline significantly by 2050.[27] Further, mirror statistics for Russia show that, in 2022, the sanctions induced Russian firms to substantially reorient their trade toward China, India, Turkey and other countries that did not impose sanctions. There are fixed costs of establishing new international trade relationships, a fact which tends to preserve trading relationships once they are established (a process known as hysteresis). As such, the long-run decline in Russia's fossil fuel exports to Europe is likely to fall further than the model estimates above, since the model estimates do not account for the decline in fuel exports to Europe due to the sanctions.

4.5. *Aggregate economic impacts of the CBAM*

4.5.1. *No-action by Russia*

The model estimates rather small impacts of the CBAM on aggregate GDP and real household income. The CBAM is estimated to reduce Russian GDP by 0.12% in the 2030–2035 period. If the US joins the CBAM coalition, the real GDP costs to Russia slightly increase to 0.14% of GDP in the 2030–2035 period. The loss of real household income is estimated at 0.3% in 2035. Further, Makarov et al. (2021, Fig. 8) estimate a shift in Russian output and exports to less carbon-intensive sectors.

4.5.2. *CBAM aggregate impacts with domestic carbon pricing by Russia*

An advantage for Russia of this policy is that the CBAM tax on Russian exports to the coalition countries will be reduced by the Russian tax or price on carbon emissions and will be zero once the domestic price of carbon emissions in Russia reaches the price in the EU. This partly explains why the aggregate cost to Russia in terms of a reduction in real consumption only falls to negative 0.5% in this scenario, compared to negative 0.3% in the scenario where Russia does not introduce domestic carbon pricing. The authors estimate a small (about 1 %) net increase in aggregate Russian exports by 2035.

Makarov et al. (2021) estimate a fall in Russian exports of carbon-intensive products to the coalition countries, but the fall is significantly less than in the scenario of the CBAM with no action by Russia. On the other hand, they estimate that domestic output of these emission-intensive sectors typically falls due to the internalization of the cost of carbon emissions, and compared with the Russia Business as Usual scenario, there is much less of an offsetting expansion of these exports to non-coalition countries.

[27] See Tarr et al. (2022, appendix A) for a summary.

5. Proposals to Solve the Climate-Change challenge

5.1. Designing an effective international cooperative climate-change agreement[28]

5.1.1. The free-rider problem

The benefits of a clean atmosphere are global public goods from which no country can be excluded, but the emissions of all countries contribute to the accumulated carbon emissions in the atmosphere. There is no global government with enforcement power to compel costly national abatement policy (and the atmosphere can't be privatized). Consequently, overcoming free riding by autonomous governments is the fundamental problem in obtaining a cooperative collective-action agreement to limit global carbon dioxide emissions.

Both theory and the empirical work presented above show that the CBAM will not fully offset carbon leakage from the abatement policies of the coalition. More importantly, reducing or neutralizing carbon leakage in the non-coalition is insufficient. In Table 4 we show that countries that are not Annex-1 countries, plus Russia, account for a about 68% of global GHG emissions. Among Annex I countries, the United States and Australia never ratified the Kyoto Protocol, while Japan, Canada and Russia withdrew from it. It is important that a cooperative agreement to reduce GHG emissions is forged that incorporates most of the Annex-I countries plus a substantial portion of the non-Annex-I countries, including the most important emitters of GHGs in both groups.

5.1.2. Cooperation: the need for trust and reciprocity

Evidence from multiple disciplines finds that the key to obtaining voluntary cooperation in common-resource problems is *reciprocity*, encapsulated in the phrase, "I will do more if you do more." The idea that reciprocity is central to cooperation is seen in large numbers of laboratory experiments, real-world systems, and theoretical studies of free-rider situations (Bowles and Gintis, 2013; Fudenberg and Tirole, 1991; Kraft-Todd et al., 2015; and Ostrom, 1990). Without reciprocity, a public-goods dilemma such as climate change will result in the tragedy of the commons. These studies indicate that, to save the commons, users must cooperate; cooperation requires trust, and trust requires a reciprocal agreement that is monitored and enforced.

Elinor Ostrom received a Nobel Prize for her seminal research on effective, real-world cooperative agreements governing common resources. In her report to the World Bank on climate change, Ostrom (2009, pp. 35-36) states that:

> Extensive empirical research on collective action [with common resources]…has repeatedly identified *trust and reciprocity* as a necessary central core associated with successful cooperative action…. When participants fear they are being "suckers" for taking costly actions while others free ride, more substantial effort is devoted to finding deceptive ways of appearing to reduce emissions while not doing so. A key problem is monitoring.

Ostrom (1990, p.59) finds that surprisingly small penalties for violating the agreement are effective at stabilizing the cooperative agreement.

5.1.3. The need for a common commitment

The research on common resources shows that the design of negotiations can result in a dramatically better outcome for global warming. A common commitment facilitates the reciprocity that is essential to surmount the free-riding problem of climate change. For a group of more than 100 countries, reciprocity requires simplification to a common commitment (Cramton et al., 2017a, 2017c). Neither the Kyoto Protocol nor the Paris Agreement obtained a common commitment; disappointing experience with these agreements has shown that national commitments which are independent of what other countries are doing will not work. The negotiators of the Kyoto Protocol attempted to define a common commitment *on quantities of emissions* from all countries based on a percentage reduction in CO_2 emissions compared to 1990 but were unable to arrive at an agreed formula. Ultimately, individual commitments were accepted, under which developing countries did not commit to emissions reductions (Cramton et al., 2017c, pp. 223–224; Depledge, 2000). Notably, the exclusion of developing countries from binding commitments was the reason that the United States failed to ratify the Kyoto Protocol.[29] Global emissions rose by 37% in the fifteen years following the signing of the Kyoto Protocol (from 1997 to 2012), with most of the global increase coming from developing countries.[30] Under the Paris Agreement, there was no attempt to obtain a common commitment. The national targets are voluntary, there is no penalty for setting under-ambitious national targets, and there is no penalty for noncompliance. Despite the NDCs, global CO_2 emissions have increased

Table 4
Greenhouse Gas Emissions (GHG) by Annex I[a] and non-Annex I Countries. GHG 2019 emissions in millions of tons of CO_2e (without LULUCF[b])

Annex 1 Countries	GHG emissions	Non-Annex I countries	GHG emissions
USA	6572	China	12,705
EU countries	4044	India	3395
Japan	1210	Russia	2123
Canada	738	Brazil	1057
Australia	546	Indonesia	1002
Turkey	508	Iran	894
United Kingdom	448	Saudi Arabia	723
Kazakhstan	360	South Korea	698
Ukraine	334	Mexico	653
Belarus	92	South Africa	555
New Zealand	82	Vietnam	450
Norway	51	Pakistan	432
Switzerland	45	Thailand	422
Iceland	5	Argentina	369
Liechtenstein	0.2	Egypt	351
Monaco	0.1	**Total of above**	25,829
TOTAL (Annex I)	15,035	**Rest of non-Annex I**	5424
		TOTAL (non-Annex I)	31,253

Source: For Annex I countries: https://di.unfccc.int/time_series, accessed August 6, 2022. World Bank database for all other data, including total emissions reported at 46,288 million tons in 2019: https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE, accessed January 6, 2023.

[a] Annex 1 countries are the developed and transition countries that are parties to the UNFCCC treaty. Russia is an Annex 1 country but is included in the non-Annex I countries.

[b] LULUCF is land use, land use change and forestry.

[28] Section 5.1 draws heavily on the consensus in Cramton et al. (2017a), a volume containing contributions by twelve leading economists who address climate-change issues, including three Nobel Prize winners.

[29] In mid-1997, the United States Senate voted 95–0 for the Byrd-Hagel resolution indicating that the Senate would reject ratification of any global treaty on GHG that would damage the United States economy or exclude developing countries. The Clinton Administration did not submit the Kyoto Protocol to the Senate, acknowledging that the condition of the Byrd-Hagel resolution, for meaningful participation by developing countries in binding commitments limiting greenhouse gases, had not been met. See: https://www.everycrsreport.com/reports/RL30692.html.

[30] Data from World Bank database at: https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE (accessed 15 April 2023). See Maamoun (2019) for analysis. See also Francisco Basetti (2022), "Success or Failure: the Kyoto Protocol's Troubled Legacy," *Foresight*, December 8. Available at: https://www.climateforesight.eu/articles/success-or-failure-the-kyoto-protocols-troubled-legacy/

since the signing of the Paris Agreement.

5.1.4. The need for a carbon-price commitment

Since there is no international government, an agreement based on emission quantities, such as a *global* cap-and-trade regime, suffers from the problem of needing to agree on national shares of the global cap. This problem proved insurmountable in the Kyoto negotiations. Contributing problems were that a common commitment on the quantity of emissions is difficult due to the complexity of comparability of quantity commitments, while the uncertainty of growth patterns introduces risk of having to buy permits on the international market.[31] A commitment to a minimum carbon price in each country avoids these problems. It is the approach we favor, and it is the consensus view of the twelve distinguished authors who contributed to the Cramton et al. (2017a) volume, among others.

It is widely accepted that carbon pricing, either by cap and trade within a country or a carbon tax, is the most cost-effective method of reducing carbon emissions at the speed and scale that is necessary. More than 2500 economists, including 27 Nobel Laureates, have signed the "Economists' Statement" in support of carbon pricing. Their statement also endorses lump-sum rebates of carbon taxes to citizens to avoid a debate on the size of government, a carbon border adjustment tax to maintain industrial competitiveness, and the removal of cumbersome command-and-control regulations.[32] Compared to command-and-control regulation, carbon pricing encourages the private sector to pursue a range of abatement options and stimulates innovation and thereby achieves environmental protection at minimum cost. Further, sixteen countries plus the 27 countries of the European Union practice *some form* of nationwide carbon pricing.[33]

Nonetheless, an *international* agreement for a minimum carbon price is required. The reason is that due to the free-rider problem, a self-interested country will price carbon emissions too low. Consider a self-interested country that experiences US$20 of damages to its own economy from a ton of its own carbon emissions, while the damage to the rest of the world from a ton of its carbon emissions is US$80. The country will have an incentive to price carbon at US$20 per ton; but since the damages are additive, a price of US$100 per ton is required to address the global damages from a ton of its emissions. That is, a self-interested country will price carbon too low since it will only correct for the damage to its own economy.

5.2. A climate Club—A solution to the free riding problem

At its meetings in June, 2022, the G7 countries agreed to form a Climate Club, but the specifics of what that Climate Club should include remain to be developed (see G7 Germany, 2022). We believe a Climate Club adapted from the proposal of Nordhaus (2015, 2018) would be our best approach to forming an effective, cooperative, international agreement on climate change.

5.2.1. The Nordhaus climate-Club proposal

Nordhaus (2015, 2018) proposes a solution to the free-rider problem in climate policy. Countries that are willing to undertake significant GHG abatement would form a Climate Club, i.e., the initial Climate Club membership would be a "coalition of the willing." Membership would be dependent on a minimum price of carbon in all member countries, to be achieved by a carbon tax, a cap-and-trade system, or a combination of these measures. Non-members would be subject to a uniform import tariff surcharge on all goods imported into member countries. That is, the import tax would not depend on the carbon content of the imported goods, as in a CBAM, but would be a surcharge on each tariff line above the tariffs otherwise applied by member countries. Once a Climate Club is formed, a non-member country faces a strategic decision of whether to join. Nordhaus assesses the decisions of countries who consider their own welfare alone, i.e., they ignore global welfare. They would choose to join the Climate Club if and only if the costs of carbon pricing in their country (net of reduced damages) are less than the costs of incurring the uniform tax penalties on their exports to Climate Club member countries.

Nordhaus uses a static version of his model (called C-DICE) to estimate the costs of the choices of countries in combination with a game-theory model to solve for what he calls stable "coalition Nash equilibria." A coalition Nash equilibrium is stable if no individual country or group of countries (sub-coalition) can improve its welfare by changing its status.

The Nordhaus Climate Club has two policy instruments: the minimum international carbon price for membership; and the uniform penalty tariff. (In section 5.2.2, we consider multiple suggestions for gradations of these instruments depending on development status.) For the Climate Club to be successful, it should choose the levels of its two instruments to accomplish two objectives: (i) attract the significant emitters of CO_2e, both in developed and developing countries, such that at least 90 % of global emissions are subject to the minimum carbon price; and (ii) impose a minimum carbon price that will significantly reduce global emissions. Nordhaus considers four target prices for carbon (US$12.5, US$25, US$50 and US$100) and all penalty tariff rates from zero to 10 % in 1 % increments. Key results are the following.

It is not surprising that the percentage of countries that join the Climate Club rises as the penalty tariff rises and falls as the minimum carbon price rises. A regime with zero penalty tariffs will dissipate to a non-cooperative equilibrium with minimal abatement. For the lowest carbon prices of US$12.50 or US$25, participation of all countries is achieved with tariffs of only 2 % or more. *With a minimum carbon price of US$50, 90% of the regions participate in the Climate Club if the tariff rate is 5 % or more.* However, for a carbon price of US$100, dramatically lower participation in the Climate Club is achieved. Even the highest tariff considered (10 %) succeeds in getting only 40% of the regions of the model in the Climate Club. This latter result is explained by the fact that the national abatement costs significantly rise with the carbon price, and the penalty tariffs under consideration are insufficient to induce high levels of membership. Paradoxically, even countries that choose not to join the Climate Club prefer a regime with small penalty tariffs and modest carbon prices to a regime with no penalties.[34] This is because the

[31] See Cramton et al. (2017b) for a detailed elaboration of the issues in this paragraph.

[32] See https://www.econstatement.org/original-cosignatories. Support also includes the IMF (Parry et al., 2021) and the World Bank (2022).

[33] For a list of countries with some nationwide carbon pricing see: https://citizensclimatelobby.org/laser-talks/carbon-prices-around-world/. The OECD report *Effective Carbon Rates, 2021* estimates how 44 OECD and G20 countries price carbon emissions from energy use (see https://www.oecd.org/tax/tax-policy/effective-carbon-rates-2021-brochure.pdf). The OECD "carbon pricing score" methodology calculates the effective carbon tax rate as the sum of tradeable emission permit prices, carbon taxes and fossil fuel use taxes. The EFTA countries, followed by the EU countries, have the highest (best) carbon pricing scores. Switzerland, with a score of 69% has the highest score in the world. Its score means that 69% of the carbon emissions in Switzerland are priced at 60 euros per ton or more in 2021. The lowest (worst) scores among the 44 countries are for the BRICS and Indonesia: Brazil (1%), Indonesia (2%), Russia (7%), China 9%), South Africa (13%) and India (13%). The United States, which has not implemented nationwide emissions trading or carbon taxes, but has fossil fuel use taxes, has a score of 22%. China has implemented a nationwide Emissions Trading System that covers 33% of its CO_2e emissions; but the price of a permit to emit a ton of CO_2e was less than two euros in 2021. See: https://www.oecd.org/tax/tax-policy/carbon-pricing-china.pdf.

[34] Higher tariffs are not considered because of the costs they will impose on member countries of the Climate Club.

benefits of strong abatement policies by members lead to benefits for non-members that outweigh the costs of low-penalty tariffs. The estimates of Bekkers and Cariola (2022) corroborate the estimates of Nordhaus that a common carbon price with a penalty tariff surcharge would be successful in inducing widespread adoption of carbon pricing.

Assessed against the principles of section 5.1, the Nordhaus Climate Club proposal meets the common commitment requirement and contains a penalty mechanism for enforcement. The Climate Club would meet the dual objectives we posited of imposing a significant minimum carbon price and attracting widespread membership. However, we must also address the important function of monitoring. One possibility is to increase funding to one of the multiple international organizations involved in carbon emissions auditing. Ostrom (1990, p.59) reports, however, that in all successful real-world cooperative arrangements, the members of the group who benefit from the common resource play a major role in the monitoring. This suggests that members of the Climate Club would need to be included in such a role.

5.2.2. *Treatment of developing countries*

The UNFCCC has adopted the principle of "common but differentiated responsibility" for the climate-change-abatement efforts of developing countries. The differentiated responsibility is partly reflected in the differentiated abatement commitments for developing countries in the Kyoto and Paris agreements, and partly in the climate-related finance provided or mobilized by developed countries for developing countries. In 2020, total climate finance provided and mobilized by developed countries for developing countries amounted to US$ 83.3 billion, which was US$ 16.7 billion short of the goal of US$ 100 billion (OECD, 2022). At the conclusion of the COP27 meeting of November 2022, the UN Climate Change press release announced what was called a "breakthrough agreement on a new 'loss and damage' fund for developing countries."[35]

We discuss several proposals for accommodating the differentiated responsibility of developing countries to a Climate Club. First, Nordhaus proposes that the poorest countries in the world would not be subject to the penalty tariff surcharge of the Climate Club, arguing that they cannot be expected to undertake GHG abatement actions. We suggest another option: the penalty tariff could be scaled depending on development status, similarly to GSP status. The staff of the International Monetary Fund (see Parry et al., 2021) suggest a third option: the minimum carbon price would be scaled depending on the development status of the country. A significant risk of the Parry et al. (2021) proposal is that it departs from a purely common commitment. Some rich countries may not participate if middle income countries that are major emitters of GHG fail to undertake common measures. For example, non-ratification of the Kyoto Protocol by the United States showed there are important political forces in the United States that are focused on equivalence in carbon reduction measures between the United States and other major developing countries. The risk on non-participation by a developed country would be significantly reduced if only the poorest countries that are not significant GHG emitters receive a lower minimum price. Further, Bekkers and Cariola (2022, p.30) estimate that, while differential carbon pricing will reduce the losses of the poorest developing countries, almost all will continue to lose real income.[36] This suggests that in order to induce membership in a Climate Club with minimum carbon pricing, an enforcement mechanism, such as penalty tariffs, would need to be imposed on developing countries that are substantial emitters of carbon emissions.

Several authors (Stoft, 2008; Cramton and Stoft, 2012; and Gollier and Tirole, 2017) have proposed a "Global Carbon Incentive Fund" that involves transfers into or withdrawals from the Fund based on the emissions of a country compared to average per-capita world emissions.[37] Since the developed countries typically have higher-than-average per-capita emissions, they would contribute into the fund, while developing countries typically would receive payments. Advantages of the Global Carbon Incentive Fund are that the formula provides incentives for all participants to reduce emissions; and, since withdrawals from the Fund would be conditional on imposition of the minimum carbon price, it would encourage carbon pricing in developing countries. However, Bekkers and Cariola (2022, p. 37) estimate that only the lowest-income developing countries would be induced by such a fund to introduce carbon pricing; that is, the top five emitters on the non-Annex I list of Table 4 would likely not introduce carbon pricing due to the fund (Russia and China would have to pay into the fund). A significant disadvantage of the Global Carbon Incentive Fund is that it reduces the likelihood that a substantial emitter of CO_2 will participate in the Climate Club.[38] With average global per-capita emissions of 4.4 metric tons in 2019, a sample of countries that would have to contribute to the Green Fund is: Canada (15.4), United States (14.7), Russia (11.8), South Korea (11.8), Japan (8.5) and China (7.6), where the numbers in parentheses are per-capita emissions in metric tons of CO_2e per year.

In our view, the existing climate finance fund for developing countries and its proposed improvement at the COP27 meeting are very useful and are an important part of the accommodation for developing countries. On the other hand, we believe there is a risk that a Global Carbon Incentive Fund would induce a major emitter (such as the US or China) to opt out of the Climate Club, and this risk outweighs its advantages. Scaling the minimum carbon price for Climate Club membership based on development status also entails risks of non-participation by some rich countries; but these risks would be significantly reduced if only the poorest countries that are low emitters of GHG have a lower minimum price. Climate Club negotiators have a difficult task in attempting to meet multiple objectives. As a start to the negotiation process, we suggest scaling the penalty tariff based on both development status and the significance of the emissions of the country, i.e., the lower the development status and the emissions, the lower the penalty tariff. Also, the poorest countries of the world who are not significant carbon emitters may become members of the Climate Club with a lower minimum carbon price. Then our recommended accommodation for the poorer countries that are not significant carbon emitters is: allow membership with a lower minimum carbon price and lower penalty tariffs for non-members, combined with the loss and damage fund agreed at the COP27 meeting.

5.2.3. *Nuances and caveats*

In their survey of Integrated Assessment Models, Gillingham et al.

[35] United Nations Climate Change, Press Release, November 20, 2022. Available at: https://unfccc.int/news/cop27-reaches-breakthrough-agreement-on-new-loss-and-damage-fund-for-vulnerable-countries

[36] All CGE models we report in this paper ignore the benefits to the economy of a clean atmosphere. Including these benefits in the Bekkers and Cariola model could reverse the sign of their estimate of real income changes. On the other hand, the Nordhaus model includes these benefits, as it is an "Integrated Assessment Model."

[37] Cramton et al. (2017b) propose that payment into or receipts from the climate fund by country i in year t would be determined by: $G_{it} = g_t \times X_{it} \times P_t$, where in year t, g_t is the generosity parameter, P_t is the global price of a ton of emissions and X_{it} are the excess emissions of country i, i.e., the tons of emissions above (or below) the estimated emissions of country i if the per capita emissions of the country were at the global average of all countries.

[38] For example, take the United States. In, average global per capita emissions were 4.4 metric tons, while in the US per capita emissions were 14.7 metric tons, and total US emissions were 4.818 gigatons. Then for the US "excess emissions relative to average" in 2019 are: $X_{US,2019} = 4.818 \times 4.4/14.7 = 1.967$ gigatons = 1.967 billion metric tons. If the price per metric ton were US$50, then P_{2019} x $X_{US,2019}$ = US$50 × 1.967 billion = US$ 98 billion. If we assume that the generosity parameter for 2019 is: $g_{2019} = 0.05$, the US would be obligated to pay US$ 4.9 billion into the Green Fund for 2019. For comparability, in this calculation we exclusively use World Bank data.

(2018) acknowledge considerable uncertainty regarding parameter values in their models. This uncertainty implies that the specific estimates are subject to a significant margin of error.

As noted above, carbon pricing, either by cap-and-trade or carbon taxes, is the most efficient regulatory mechanism for carbon emissions. If the Climate Club can induce a country to join, the minimum carbon-emission price overcomes a major weakness of carbon border adjustment mechanisms, which is that it only taxes a minority of carbon emissions. The Climate Club does not constrain the trade policy of its members other than in the imposition of a penalty tariff surcharge on non-members. Then a Climate Club member may choose to impose a CBAM to preserve industrial competitiveness.

Third, the pricing of carbon in a larger share of the global economy will endogenously increase the demand for technologies that reduce carbon emissions and induce more private investment in those technologies. This endogenous response by the private sector to carbon pricing is not included in the Nordhaus C-DICE model or the other model estimates we have cited in this paper but is an additional benefit of the Climate Club.

Fourth, Nordhaus maintains that due to terms-of-trade effects, if a country imposes a small uniform tariff starting from zero tariffs, it obtains benefits. He infers from this that the members of the Climate Club gain from imposing tariffs up to a uniform tariff surcharge of 10 %. Virtually all countries in the world, however, have a regime with positive tariffs and many include some sectors with high tariffs (tariff peaks). Imposing a tariff surcharge on top of a tariff line which is a tariff peak will likely induce loses, reducing the estimated gains from participation in the Climate Club. Since a CBAM imposes higher tariffs on a much smaller set of products, a disadvantage of the CBAM is that it will very likely impose costs on the country imposing the tariffs.

Despite these qualifications, the estimates of Nordhaus provide considerable insight into the types of policy actions (and the range of values its instruments may take) that may be undertaken by the global community to achieve high levels of GHG mitigation. The Climate Club, as outlined by Nordhaus, appears crucial for the global community to move toward a cooperative solution to the challenge of global warming.

5.3. Subsidies for game-changing basic research

We see the need for technology to lower the cost of green energy production so that it will be adopted as a least cost method of producing energy. Making green energy the least-cost choice is especially important in inducing green energy adoption in developing countries. This view is shared by diverse analysts of Climate Change[39] including the Breakthrough Energy group of private investors founded by Bill Gates:

> Many existing energy options have a built-in advantage of being less expensive than newer green ones. That's because their price does not factor in the environmental damage they cause around the world. Our goal is to reduce the [advantage] through programs, investments, and policies that help bring down the costs of clean technologies, so consumers and industries will use them.[40]

We see an important role for governments of rich countries to subsidize basic research in game-changing technologies that would make the adoption of clean technologies the least-cost option. This includes nuclear, solar, and wind with cheap mass storage, fusion, biofuels, carbon capture and others. Further, there may be cases where carbon pricing is inefficient at controlling emissions and technological solutions work better.[41] Investment today in game-changing carbon reduction technologies will, if successful, generate important externalities for the world. But before investments reach the stage of possible commercialization, it is typically difficult to find private financing. Further, it is understood that research and development generate spillovers, including environmental externalities that are not always captured by firms that invest in the technology. For example, after the expiration of a patent, the innovating firm will only partly capture the gains from the invention. The invention of firm A may allow firm B to improve upon the original invention (learning by doing), whereby firm B may capture more of the benefits.[42] In the context of this rationale, in February 2021, the United States Department of Energy announced funding of up to US $100 million for transformative clean energy solutions. It was reported that billions more of these subsides are planned.[43]

If high income countries were to devote 0.2% of their GDP[44] to basic research on game-changing technologies, US$ 118 billion per year would be available for basic climate-change research. In contrast, the International Monetary Fund (IMF) estimates that fossil fuel subsidies are about fifty times this number at US$ 5.9 trillion annually, of which US$ 500 billion are explicit subsidies and US$ 5.4 trillion are implicit subsidies (which take into account all social costs).[45] While some aspects of the IMF's implicit-subsidies methodology could be questioned,[46] even the explicit subsidies for fossil fuels are more than four times the value of this recommendation for transformative research on clean energy.

5.4. Complementary proposals

We see the proposal to fund basic research on game-changing climate technologies and the proposal for a Climate Club as complementary rather than mutually exclusive. By pricing carbon emissions, the Climate Club would incentivize investment in technologies that reduce carbon emissions.[47] Conversely, new technologies that lower the cost of reducing carbon in the atmosphere would encourage more countries to join the Climate Club, since the costs to their economies of pricing carbon would decline.

6. Implications for the World Trade Organization (WTO)

A key problem for this Climate-Club proposal is that many countries would have to exceed their bound tariff levels at the WTO for some of

[39] For example, Bjorn Lomborg proposes substantial funding for transformative energy research that would make clean energy cheaper than fossil fuels. See: https://www.theglobeandmail.com/opinion/article-at-cop26-lets-not-repeat-our-failed-climate-strategies/.

[40] https://www.breakthroughenergy.org/

[41] For example, carbon taxes may not be effective in the livestock production sector due to the difficulty of monitoring the emissions of the large number of wandering animals. Among others, however, Roque et al., 2021 report that supplementation of seaweed in the feed of beef steers reduces methane emissions by over 80 % while also reducing the cost of production per kilogram of weight gain by the steers. To realize these transformative environmental benefits along with the economic gains, however, it is necessary to develop aquaculture and processing techniques for seaweed.

[42] See Gillingham (2019) for a similar view on the justification for government support for green technology.

[43] https://www.energy.gov/articles/doe-announces-100-million-transformative-clean-energy-solutions

[44] The world GDP in 2021 was USD 96 trillion of which high income countries GDP was USD 59 trillion and the United States GDP was USD 23 trillion. See: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

[45] See: https://www.imf.org/en/Topics/climate-change/energy-subsidies#Energy%20Subsidies

[46] For example, the IMF includes road congestion costs as an implicit social cost of fossil fuels; but it is questionable that clean energy sources for autos would substantially reduce road congestion costs.

[47] Sabel and Victor (2022) advocate an "experimental" approach to technological innovation for climate change that encourages innovation at the local or industry level with diffusion of the best technologies through shared results globally. Like us, Sabel and Victor (2022, p. 166) see a key role for carbon pricing in encouraging technological innovation and the need to facilitate financing for developing countries for technology adoption.

their tariff lines in contravention to GATT (1947, Article II). In addition, since the Climate Club members would only apply the penalty tariff to WTO member countries that are not members of the Climate Club, members of the Climate Club would violate the Most Favored Nation (MFN) principle of the WTO, GATT (1947, Article I).

In our view, the WTO and its predecessor, the GATT, have provided an international rules-based framework that has facilitated the reduction of trade barriers and an international trade regime that has led to very substantial benefits to the global community, including poverty reduction. Any dramatic changes that would weaken the WTO should not be taken lightly. Considering the grave nature of the climate challenge, we discuss three approaches that may allow a Climate Club within the framework of WTO law.

6.1. A WTO amendment

Nordhaus proposes an Amendment to the WTO rules to accommodate a Climate Club. The difficulty with an Amendment to the law of the WTO is that, based on historical experience, passing it probably would entail time-consuming negotiation among WTO members to obtain the required consensus, in addition to the requirement for two-thirds of WTO members to ratify the amendment into national law.[48] There have been only two amendments to the WTO (1994) agreement: the Trade Facilitation Agreement amendment, and an amendment to the Trade Related Intellectual Property (TRIPS)[49] agreement. In both cases, it took about twenty years for these amendments to become law.

In the case of the Trade Facilitation Agreement, there was significant resistance from many developing countries that delayed formal negotiations. Developing countries preferred recommendations as opposed to mandatory trade-facilitation rules.[50] To obtain the agreement of developing countries, the Trade Facilitation Agreement allows developing countries to opt-out of the obligation to undertake a commitment if they lack adequate implementation capacity.

Judging by the difficult negotiations on the Trade Facilitation Agreement, an Amendment to accommodate a Climate Club could be expected to be very contentious and time-consuming, and may necessitate allowing developing countries to opt-out if they determine that they do not have the capacity to implement the obligation. This means there would be a lack of reciprocity in the agreement from developing countries. We have argued in section 5.1 that reciprocity is the essential feature required for a successful international cooperative climate agreement. Although it is useful to seek an Amendment for the Climate Club, an effective legal strategy should go beyond this.

6.2. A WTO waiver

In the case of the TRIPS amendment, WTO members voted in 2003 to provide a “Waiver” for qualifying poor countries under the terms of the proposed Amendment. This meant that the qualifying poor countries received the benefits of the Amendment 14 years prior to its passage into WTO law. A Waiver to the rules of the WTO usually requires a vote of three-fourths of WTO members (WTO, 1994, Article IX.3)[51] and is subject to annual review and voting for its extension. A negotiation within the WTO to obtain the required votes for a Waiver, however, is also likely to take considerable time and, due to the annual review requirement, it would not be a permanent solution. It may be useful to pursue a Waiver simultaneously with an Amendment, as in the case of TRIPS, but an effective legal strategy should also go beyond a Waiver.

6.3. A WTO exception

Article XX (b) of the GATT (1947) allows members to adopt measures to “protect human, animal or plant life health” provided such measures do not “constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade.” The kinds of climatic changes scientists envision from global warming would threaten human, animal and plant health, and would justify measures to reduce GHG emissions even if these measures violate the MFN and the bound tariff rules of the WTO. Exceptions do not require approval of other members, so may be implemented promptly. In principle, an Exception is subject to a challenge by other members under the Dispute Settlement Mechanism of the WTO. There are two reasons to believe that immediate implementation of a Climate Club under the Exception justification of GATT Article XX (b) would not be reversed under the Dispute Settlement Mechanism, at least for many years. First, due to the global benefits of a clean atmosphere, one wonders which country would become a complainant in a Dispute Settlement Process. Second, the Dispute Settlement Mechanism is not currently functioning; until it begins functioning again, the Dispute Settlement Body cannot rule against any Exception.[52] Given the urgency of an effective international cooperative agreement on climate change, we recommend use of the Exception clause under Article XX of the GATT. This does not preclude seeking an Amendment. On the contrary, the Climate Club members would prudently pursue all options.

7. Conclusions

Empirical work shows that a CBAM should be successful at improving the competitiveness of domestic firms in energy- and trade-intensive industries against imports from countries with weak carbon regulations. This should contribute to the political viability of efficient carbon pricing. The CBAM will also reduce (but not eliminate) carbon leakage. Reducing carbon leakage, however, is insufficient for meeting global climate objectives. Rather, it is necessary for a large share of the world with weak regulatory policies to also reduce their carbon emissions. We presented both the theory and empirical results that show how CBAMs are very inefficient at reducing global carbon emissions.

We discussed two proposals for solving the global climate crisis that we believe hold considerable promise. One proposal is for a Climate Club of countries, in which membership requires a country to impose a minimum carbon price at home and impose a uniform tariff surcharge on all imports from all countries that are not members of the Climate Club. For developing countries that are not significant emitters of carbon, we suggest allowing the poorest countries in the world that are low emitters of CO_2e to join the Climate Club with a lower minimum price and lower penalty tariffs would be imposed on these countries that are not members. Since the Climate-Club members employ an economy-wide carbon price, they are using the instrument widely understood to be the most efficient way to control carbon emissions and, if properly balanced, model estimates indicate that the penalty tariff will induce widespread international membership at a carbon price that significantly reduces emissions. Climate Club members would be free to also employ a CBAM or otherwise change their own trade policies.

The penalty tariff of the Climate Club would violate the MFN principle of the WTO as well as cause many members to exceed their bound tariff commitments on some tariff lines. We assess three approaches for Climate Club members to act within WTO law: an Amendment, a Waiver

[48] Amendments that relate to either MFN or bound tariffs must be adopted by consensus. See World Trade Organization (1994, Article X) for the rules and process for an amendment to the WTO.

[49] For details of the TRIPS Amendment see: https://www.wto.org/english/news_e/news17_e/trip_23jan17_e.htm

[50] See Neufeld (2014) for details.

[51] A consensus is required in some cases.

[52] The WTO states that: “Currently, the Appellate Body is unable to review appeals given its ongoing vacancies. The term of the last sitting Appellate Body member expired on November 20, 2020.” See: https://www.wto.org/english/tratop_e/dispu_e/appellate_body_e.htm

and an Exception. We recommend that a Climate Club apply its penalty tariff under the Exception clause of the GATT, since it could legally and immediately apply the penalty tariff. For the penalty tariff to become illegal, the Dispute Settlement Mechanism would have to be reactivated, some WTO member-country would have to initiate a Dispute Settlement case, and the penalty tariff would have to be declared illegal in the process. It would also be prudent to also seek an Amendment.

The second proposal is that all high-income countries of the world would devote 0.2% of their GDP to subsidizing basic research to attain game-changing technologies. The objective is to make it less expensive to employ green energy over fossil fuels and thereby induce widespread adoption of clean technologies. We see the proposals for a Climate Club and subsidies for transformative research as complementary proposals rather than mutually exclusive.

Our detailed case study of impacts on the Russian Federation of climate policies shows that the proposed CBAM of the EU will have only small impacts on the aggregate welfare and carbon emissions of Russia. On the other hand, domestic carbon pricing by Russia would have a very strong impact on reducing its GHG emissions. These results support the broader theme of the superiority of economy-wide carbon pricing over a CBAM for the purpose of carbon reduction.

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David G. Tarr: Supervision, Formal analysis, Conceptualization, Writing – original draft. **Dmitrii E. Kuznetsov:** Investigation, Data curation, Writing – original draft. **Indra Overland:** Conceptualization, Funding acquisition, Writing – review & editing. **Roman Vakulchuk:** Funding acquisition, Project administration, Investigation, Writing – review & editing.

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