Trade, Emissions and Environmental Spillovers: Issue linkages in Regional Trade Agreements

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Abstract

Reducing trade barriers offers tremendous potential for economic growth and productivity gains. However, higher incomes and increased industrial output can negatively impact the environment. We study the impacts of trade liberalization on the emissions of ozone depleting substances controlled under the Montreal Protocol. While freer trade might challenge the gains achieved by the Montreal Protocol by increasing domestic use of CFCs and other ozone depleting substances, environmental provisions in regional trade agreements (RTAs) linked to Montreal Protocol participation might mitigate such negative environmental outcomes. We provide causal evidence that signature of new RTAs leads to increases in ODS consumption relative to Montreal Protocol targets. Environmental provisions aimed at controlling ozone depleting substances offset the increase in ODS consumption observed in RTAs without such provisions. We find that the effect is rooted in preventing a "reduction in overcompliance" to the Montreal Protocol observed in RTAs without provisions.

Keywords: Ozone Depleting Substances, Regional Trade Agreements, Trade Liberalization, Montreal Protocol, Environmental Policy

JEL Classification Codes: F14, F18, Q53, Q56

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1 Introduction

The Montreal Protocol has been one of the most successful international environmental agreements in history, effectively eliminating the use of ozone depleting substances (ODS) and allowing for the eventual repair of the stratospheric ozone layer (Gonzalez *et al.*, 2015; World Meteorological Organization, 2018; McKenzie *et al.*, 2019). The success of the Montreal Protocol in part stems from it's nearly universal set of member countries, including all members of the United Nations, Palestine, and the European Union.[1]. The Montreal Protocol incentivizes developing countries to comply by giving them more time to phase out substances than developed countries, offering technical and financial assistance to utilize new substances, and mandating members limit trade with countries not party to the agreement. The Montreal Protocol also features clearly enumerated dispute settlement procedures to address member party noncompliance. However, dispute settlement resolution under the Montreal Protocol focuses on assisting non-conforming countries to move into compliance—punishment mechanisms are fairly limited to extreme cases in which a country loses signatory rights and privileges.[2]

In this paper we consider the impacts of linking trade liberalization, in the form of regional trade agreements (RTAs), to the Montreal Protocol and ODS reduction commitments more broadly. RTAs increasingly contain detailed provisions on environmental issues—a phenomenon broadly understood as a type of "issue linkage" in which two unrelated policy areas are tied together (Maggi, 2016). Linking Montreal Protocol and ODS commitments to trade policy under RTAs introduces the potential for additional punitive measures for non-compliance in the form of retaliatory trade policy allowed for under RTA dispute settlement mechanisms. Because these expanded punitive measures fall under the RTA rather than the Montreal Protocol, they potentially cover a broad set of goods and services rather than the narrow focus on ODS-related goods under the Montreal Protocol.

We consider two aspects of issue linkages between trade and environmental policy using detailed data on trade agreement content from the World Bank's Deep Trade Agreement database. First,

[1] https://ozone.unep.org/classification-parties

[2] "Indicative list of measures that might be taken by a Meeting of the Parties in respect of non-compliance with the Protocol:" https://ozone.unep.org/node/2080

we empirically investigate the use of trade agreements to induce accession to international environmental agreements—a phenomenon referred to as "participation linkage" in the literature. Because the Montreal Protocol limits trade in ODS-related goods with non-member countries, members countries may push to include Montreal Protocol accession as requirement in a trade agreement with non-members in order to more effectively open trade and eliminate trade barriers under the Montreal Protocol. Second, we consider "enforcement linkage" between trade agreements and reductions in emissions of ozone depleting substances. In contrast to participation linkages—in which commitments bind via the Montreal Protocol—we also consider ODS commitments directly enumerated in trade agreements themselves that bind via RTA dispute settlement mechanisms. In particular, we study whether such enforcement linkages are effective at mitigating ODS emissions. This is a critical question in light of recent evidence that China has increased production and consumption of CFC-11 in violation of it's Montreal Protocol commitments (Rigby *et al.*, 2019).

We find evidence of enforcement linkage effectiveness in RTAs that include these provisions. While most countries are in compliance with Montreal Protocol ODS targets, we find that trade liberalization leads to an increase in many ODS relative to Montreal Protocol targets, with a *reduction in overcompliance* to the Montreal Protocol. In other words, RTAs induce countries to increase their use of ODS, while still maintaining compliance with the Montreal Protocol. We find evidence that the inclusion of Montreal Protocol and ODS provisions mitigates or entirely reverses these effects for many ODS. We do not find that the effectiveness of these provisions hinges on the enforceability of the provisions under the RTA dispute settlement process, suggesting that linkage to a binding and enforceable international agreement is adequate to generate responses in ODS consumption.

This paper makes important, policy-relevant contributions to a number of literatures. First, this paper is one of the first, if not the first, to empirically consider participation linkages in trade agreements. Second, we contribute to the broad literature on the relationship between trade and the environment. A large share of this literature has studied the impacts of trade on pollution (Antweiler *et al.*, 2001; Frankel and Rose, 2005; Managi *et al.*, 2009; Kreickemeier and Richter, 2014; Cherniwchan, 2017) while other work focuses on trade and renewable resource management

(Brander and Taylor, 1998; Hotte *et al.*, 2000; Bulte and Barbier, 2005; Copeland and Taylor, 2009; Taylor, 2011; Erhardt, 2018), especially deforestation (Abman and Lundberg, 2020; Barbier and Rauscher, 1994; Sohngen *et al.*, 1999; Hannesson, 2000; Leblois *et al.*, 2017; López and Galinato, 2005; Barbier *et al.*, 2005; Barbier and Burgess, 2001). Very little of the literature has established causal evidence of the impacts of trade on the environment. Most of these papers rely on either cross-sectional variation or within-country variation in observed trade volumes or trade measures to study this relationship using either pooled ordinary least squares or fixed-effects regressions. We build upon the new, but quickly growing, quasi-experimental literature on the impacts of environmental content in RTAs (e.g. Abman *et al.*, 2021; Abman and Lundberg, 2020; Erhardt, 2018; Leblois *et al.*, 2017) —through both participation linkages as well as the effectiveness of ODS provisions in RTAs .

We also contribute to a small economics literature exploring the Montreal Protocol (Murdoch and Sandler, 1997; Beron *et al.*, 2003; Auffhammer *et al.*, 2005; Ivanova, 2007). While scientific evidence suggests that the agreement was successful in reducing ODS (Velders *et al.*, 2007; Morgenstern *et al.*, 2008; Fortems-Cheiney *et al.*, 2015; Chipperfield *et al.*, 2015; McKenzie *et al.*, 2019), there is a dearth of rigorous econometric studies using contemporary causal identification strategies on the impacts of the Montreal Protocol. The shortage of economic studies on the Montreal Protocol is a critical gap in the literature, especially in light of the Montreal Protocol's ongoing relevance, especially the recent Kigali Amendement that established phase out schedules for hydrofluorocarbons (F-gases, or HFCs)—powerful greenhouse gases with global warming potentials that dwarf that of carbon dioxide.

The remainder of the paper proceeds as follows. In Section 2 we provide an overview of the institutional setting with a particular focus on the Montreal Protocol and ODS commitments along with our data sources. We outline our empirical strategy in Section 3 and present our results in Section 4. We offer some concluding remarks in Section 5.

2 Background and Data

2.1 Regional Trade Agreements

Regional trade agreements, beyond eliminating trade barriers between countries, often address non-trade policy areas in their content such as competition policy, intellectual property, and environmental concerns. Non-trade commitments within RTAs have proliferated in recent decades, both in number and in policy scope - the average RTA in the 1950s covered eight policy areas; in recent years they have averaged 17 (Hofmann *et al.*, 2017). The increasing number of policy commitments has been accompanied by an increase in regulatory and enforcement requirements. The changing nature of RTAs is documented in a new database by the World Bank detailing the content of all RTAs in force and notified to the World Trade Organization (Mattoo *et al.*, 2020).

Our data on environmental provisions in RTAs have been collected as part of the broader World Bank project on the content of trade agreements and are described in detail in Monteiro and Trachtman (2020). This is the most extensive effort to date to document environmental provisions in trade agreements. The environmental provisions coded include environmental goals, specific commitments, compliance with multilateral environmental agreements, enforcement mechanisms, and external assistance and collaboration. Within this set of environmental provisions, we select two that address ozone depleting substances:

- Does the agreement require states to control ozone-depleting substances?
- Does the agreement require states to comply with the Montreal Protocol on ozone depleting substances?

Figure 1 displays the frequency of RTAs over time, as well as the inclusion of provisions related to ODS. With the discovery of the ozone impacts of chlorofluorocarbons occurring in the 1970s and the signing of the Montreal Protocol occurring in 1987, it is unsurprising that the first provisions in trade agreements relating to ODS appeared in the mid-1990s. The list of trade agreements containing provisions on ODS use is displayed in Appendix Table A1. There are 44 agreements that include at least one of the two provisions related to ODS. 23 of these agreements (not including

the TPP or NAFTA) are between either the US, the EU, or Canada, and another party. 27 of the agreements (also not including the TPP or NAFTA) involve at least one South or Central American country. 36 of the agreements contain provisions that are legally binding with dispute settlement mechanisms available under the RTA.

2.2 The Montreal Protocol

The consumption and production of ozone depleting substances (ODS), such as chlorofluorocarbons, hydroclorofluorocarbons, halon gases, and methyl bromide, is regulated by the Montreal Protocol. Signed in 1987, the Montreal Protocol is considered a landmark piece of international policy, as it has 1) achieved universal ratification by members of the United Nations and 2) successfully reduced the use of ODS, beginning the recovery of the stratospheric ozone layer (World Meteorological Organization, 2018).

Originally covering only a handful of chlorofluorocarbons (CFCs) and halons, the Protocol has been amended five times, increasing its scope to cover carbon tetrachloride (CTC), trichloroethane (TCA) and other fully halogenated CFCs in the London Amendment of 1990; hydrochlorofluorocarbons (HCFCs), hydrobromofluorocarbons (HBFCs) and methyl bromide (MB) in the Copenhagen Amendment of 1992; bromochloromethane (BCM) in the Beijing Amendment of 1999; and hydrofluorocarbons (HFCs) in the Kigali Amendment of 2016.[3] While HFCs do not have the ozone depleting potential of the substances previously added to the MP, they are a common substitute to CFCs and HCFCs and a potent greenhouse gas.

The phaseout schedules for the consumption and production of ODS vary by the substance and are based on a countries historical usage. The specific dates and targets for phaseout are determined by a country's status as a developed or developing country, as of the time of signing. Developing countries, referred to as "Article 5" countries, are given more time and are allowed to delay implementation of control provisions.

For example, the phaseout schedule for methyl bromide for non-Article 5 countries specifies a

[3] https://ozone.unep.org/treaties/montreal-protocol-substances-deplete-ozone-layer/the-evolution-of-the-montreal-protocol

country's base level of consumption as its total consumption in the year 1991, and mandates the country freezes its MB consumption at its base 1991 level in 1995. It then requires 1999 consumption to be at most 75% of the base level, and 2001 consumption to be at most 50% of the base level (followed by 30% in 2003 and 0% in 2005). For Article 5 countries, the base level is set to average yearly consumption over the period 1995-1998. Consumption is required to be at or below base level in 2002, at most 20% of base level in 2005, and 0% in 2015.

Table 1 displays the ozone depleting substances regulated under the Montreal Protocol, along with the treaty that introduced their phaseout, and specified dates for 0% consumption and production for each ODS type for Article 5 and non-Article 5 countries. The Montreal Protocol groups ODS types into "Annexes" based on introduction date and phaseout schedule. ODS are generally used as refrigerants, aerosol propellants, cleaners, fumigants, and in fire suppression. All Annex A and B gases (CFCs, halons, other CFCs, CTCs, and TCA) are phased out for developed countries by 1996, while Article 5 countries have until 2010 to complete their phaseouts (2015 for TCA).

Table A4 in the Appendix lists all non-Article 5 and Article 5 parties. There are 51 non-Article 5 parties and 147 Article 5 parties. Non-Article 5 parties include the European Union, the United States, Canada, Japan, and the Russian Federation; Article 5 countries include China, India, South Korea, Turkey, and Brazil. Article 5 designation was determined by the country's consumption of Annex A substances (CFCs and halons) at the time of Montreal Protocol entry into force in 1989 - countries with consumption of less than 0.3 kg per capita were given Article 5 status.

The Montreal Protocol's procedures on non-compliance are simple. Non-compliance includes when a country's consumption or production exceeds the level allowed by its phaseout schedule. Examples of non-compliance also include failure to report data to the Ozone Secretariat or failure implement a licensing system for substances within the country by the mandated date. The treaty outlines three measures that might be taken in the event of non-compliance - appropriate assistance in data collection, data reporting, technology transfer, or funding; issuing cautions; and suspension "in accordance with the applicable rules of international law concerning the suspension of the operation of a treaty" Brack (2003). Suspension would imply loss of trade privileges in ODS-related goods with countries party to the Protocol or loss of financial assistance. as of 2022, no

party has been suspended to date.

2.3 Participation and Enforcement Linkages

This paper considers two potential types of linkages RTAs can exhibit to the Montreal Protocol. The first, "participation linkage" refers to the potential for trade agreements to contain specific clauses in order to induce accession to the Montreal Protocol. The treaty disallows trade in ODS-related products with countries not party to the Montreal Protocol, so countries may include provisions in trade agreements to ensure their trading partner's status with the Protocol.

The Montreal Protocol is made up of the original 1987 treaty and five amendments introducing new substances (1990, 1992, 1997, 1999, and 2016), each of which needs to be ratified by a country's legislature. Figures A.1-A.3 in the Appendix display histograms of the years in which the original treaty and its amendments are ratified. Besides the most recent amendment in 2016, all five amendments and the original treaty maintain near universal ratification. However, ratification rarely occurs quickly after the signing - across Article 5 and non-Article 5 groups there are countries that take decades for a country to ratify the treaty. It took until 2012 to achieve universal ratification of the 1990 and 1992 amendments, and 2014 for the 1997 and 1999 amendments. Dozens of countries have yet to ratify the Kigali Amendment of 2016. These years of noncompliance might endanger trade relations with countries that have already ratified the treaty, potentially inducing countries to include specific language in trade agreements mandating accession.

The second type of linkage, "enforcement linkage" refers to additional ODS commitments directly enumerated in trade agreements that bind via RTA dispute settlement mechanisms. While the World Bank's Deep Trade Agreement database does not specify if a provision targeted any specific substance, comparing the timing of provisions to each substance's phaseout schedule reveals some patterns that may be informative to why the provision were included. Figures 2 and 3 display the phaseout schedules of each of the regulated substances of the Montreal Protocol for non-Article 5 and Article 5 countries, respectively. In each plot, the frequency of RTAs with provisions related to ozone depleting substances over time is also displayed in the form of a histogram. Figure 2 reveals that the majority of RTAs with ODS provisions enter into force after non-Article 5 countries have

completed their full phaseouts of most substances regulated by the Montreal Protocol, with the exception of MB, HCFCs, and HFCs. Since Article 5 countries are given more time to complete their phaseouts, as Figure 3 displays, the passage of RTAs with ODS provisions in the 2000s and 2010s aligns with the phaseout schedules of most substances for Article 5 countries. This timing aligns with the observation that half of treaties with ODS provisions (22 out of 44) are between one non-Article 5 country and one or more Article 5 countries, and only two treaties are between two non-Article 5 countries (EU-Ukraine and EU - San Marino).

Figure 4 presents an alternative display of the timing of ODS provisions compared to each substance's phaseout schedule. For each substance, the entry into force of each of the 44 treaties with ODS provisions is compared to its phaseout schedule for Article 5 and non-Article 5 countries. Whether its entry occurs before the start of the phaseout, during, or after the phaseout is shown for both Article 5 and non-Article 5 countries. For TCA and MB, about 3/4 of provisions are passed after the non-Article 5 phaseout schedule and during the Article 5 phaseout schedule. The majority of provisions are passed before the Article 5 phaseout schedule for HCFCs and HFCs.

2.4 UNEP Consumption Data

To measure the impact of ODS provisions in trade agreements on a country's ODS use, we use data on the consumption of ODS taken from the United Nations Environment Programme database.[4] The data are reported at the country-year level in ozone-depleting tonnes. We target seven of the ten substances regulated by the Montreal Protocol reported by UNEP: CFCs, halons, other CFCs, CTC, TCA, HCFCs, and MB. We omit HBFC, BCM, and HFCs as data are only available for a handful of countries.

Since ODS consumption is bound by the phaseout schedules delineated by the Montreal Protocol, a country's ODS consumption from UNEP needs to be normalized by the country's baseline in order to determine how out-of or in-compliance the country is and how trade agreements impact compliance. We construct yearly consumption targets for each country and substance, based on the phaseout schedules dictated by the Montreal Protocol. The Montreal Protocol does not specify

[4]https://ozone.unep.org/countries/data

yearly targets, only dates for key reduction targets. For example, for Article 5 countries, 2007 CFC consumption can be no more than 15% of base level, and 2010 consumption can be no more than 0% of base level. For each gas, for years in between specific target dates, we do a linear interpolation to produce the consumption targets. For the example above, the 2008 target would be 10% of base level, and 2009 5% of base level. We then take the difference between each country's substance consumption and target value. If the value is positive, the country is consuming at a level above the interpolated target, and an increase represents an increase in substance consumption. If the value is negative, the country is "in compliance."

2.5 Dataset Construction

For our analysis we employ a "stacked" country-level panel with a ±3 year event window around signature of any RTAs. To do so we consider every year an RTA enters into force for a country and include three years before and three years after. If a country has multiple RTAs enter into force in adjacent years, each of ±3 year event windows enter into the analysis dataset separately and are "stacked" or pooled. The resulting panel consists of 265 RTAs and 874 individual seven year country sequences.

3 Empirical Strategy

We identify both the effects of trade liberalization on our emissions outcomes as well as the impact of ODS provisions in RTAs with the following triple-difference model on our stacked country panel:

$$ihs(dev_{igt}) = \beta_1 RTA_{igt} + \beta_2 RTA_{igt} * ODS_{ig} + \alpha_{ig} + \varepsilon_{igt} \tag{1}$$

where i indexes countries, t indexes years, and g indexes RTAs with $ihs(dev_{igt})$ is the inverse hyperbolic sine of deviation in consumption of ODS from the target levels under the Montreal Protocol. $RTA_{igt} = 1$ if year t is later than the year that RTA g is signed and zero prior, and $ODS_{ig} = 1$ if RTA g includes the Montreal Protocol or ODS provisions. α_{ig} is a country-RTA fixed

effect that ensures that estimated treatment effects are relative to the preperiod for each country and each RTA. Country characteristics such as political, legal and religious institutions, persistent demographic profiles, and time-invariant comparative advantages (e.g. driven by population size or geography) are accounted for via the inclusion of α_{ig}. This fixed effect specification also controls for all RTA-level factors that might lead to endogenous content formation like signatory countries' baseline ODS consumption levels, accession to the Montreal Protocol and subsequent Amendments, political economy factors between signatories like relative bargaining power or industry lobbying pressures. Note that we do not include time fixed effects since doing so would change our within country-RTA reference unit. We note that since our event window is fixed in time for each RTA, our country-RTA fixed effects does provide for some control of time in our model. We also note that our target deviation outcomes also account for time and ODS drawdown schedules.

As argued in Abman and Lundberg (2020) and Abman *et al.* (2021), entry into force of RTAs requires separate, independent ratification from all signatory countries[5], countries cannot unilaterally enact the RTA which creates plausibly exogenous variation in the timing of RTA policy exposure. Hence, our triple difference parameters recover plausibly causal impacts of trade liberalization. In Model (1), β_1 captures the changes in country outcomes after the signature of an RTA without ODS provisions while β_2 captures the differential effect from RTAs with relevant provisions. Thus, signature of RTAs that include labor provisions will lead to an estimated $\beta_1 + \beta_2$ increase in the outcome variable. We focus on signature, rather than entry into force of RTAs, because countries are already faced with targets under the Montreal Protocol. By signing an RTA linked to the Montreal Protocol, countries are exposed to potential RTA disputes related to Montreal Protocol noncompliance whenever the RTA enters into force. Abman and Lundberg (2020) illustrates the effectively random timing of entry into force of signed RTAs, hence we expect potential country-level response to these provisions to occur around signature, rather than entry into force. For robustness, we also include in the Appendix triple-difference estimates around entry into force rather than signature.

We also consider the role that enforcement linkages play in ODS outcomes. To do so we add an additional differencing dimension (i.e. a quadruple difference model) about whether the provisions

[5]Note: not always "all."

are binding and enforceable via dispute settlement mechanisms:

$$ihs(dev_{igt}) = \beta_1 RTA_{igt} + \beta_2 RTA_{igt} * ODS_{ig} + \beta_3 RTA_{igt} * ODS_{ig} * Bind_{ig} + \alpha_{ig} + \varepsilon_{igt} \quad (2)$$

where $Bind_{ig} = 1$ if agreement g for country i features ODS provisions that are binding and enforceable via dispute settlement.

For all empirical specifications, we report two-way, cluster-robust standard errors clustered at the country-RTA level—to account for temporal autocorrelation within treatment units—and at the country-year level—to account for correlation across RTA "stacks" that might arise from overlapping, adjacent RTA treatment at the country level.

4 Results

We present our main findings in Table 2 for regressions of the inverse hyperbolic sine of ODS consumption relative to target levels under the Montreal Protocol. We find that trade liberalization significantly increases deviations from targets for Annex A gases. However, the mean level of our outcome variable is negative, indicating overcompliance in Montreal Protocol commitments. CFC target deviation from target increases by approximately 70% after RTA signature, which corresponds to a reduction in overcompliance of approximately 980 ODP tonnes. On average, this corresponds to an increase in 100-year global warming potential (GWP) equivalent to 7.7 million tons of carbon dioxide.[6] Halon deviation from target increases by approximately 37% after RTA signature, which corresponds to a reduction in overcompliance of approximately 97 ODP tonnes. We reiterate that, on average, countries are still in compliance with Montreal Protocol targets following signature of RTAs, the targets are simply less slack than they were before an RTA. We estimate positive coefficients on target deviations of Annex B (other fully halogenated CFCs, CTC, and TCA) gases after RTA signature, however none of these coefficients is statistically differentiable from zero. We estimate a negative responses in target deviations for HCFCs and Methyl Bromide

[6] UNEP CFC data does not differentiate CFC gases in ODS consumption data. Different CFC gases have different global warming potential. Our calculation here is based on the average GWP across all CFCs.

after RTA signature, although only the HCFC effect is significant.

We find fairly broad evidence that the inclusion of ODS and Montreal Protocol provisions in RTAs lead to significantly negative response on target deviations for both Annex A gases (CFCs and halons) and from most Annex B gases (CTC and TCA). Negative point estimates here correspond to *increases* in overcompliance, i.e. the Montreal Protocol targets become even more slack with the inclusion of the provisions. For CFCs, CTC, and TCA, the provision magnitude is such that in RTAs with these provisions the net effect of signature is negative—overcompliance increases after signature for all three gases. For halons the inclusion of the provisions offsets the RTA signature effect such that in RTAs with the provisions there is no net change in compliance after signature. We report event study coefficients with 95% confidence intervals for these triple-difference regression in Figures 5–11.

4.1 Enforceable Provisions

Our results in Table 2 suggest that the provisions do indeed appear to be effective for many of the substances in our study. We explore this effectiveness further by considering provisions that are binding and enforceable with access to dispute settlement mechanisms under the RTA. We report estimates of Equation (2) in Table 3. Notably, the mitigating effects of ODS provisions on Annex A emissions do not hinge on the enforceability of such provisions via RTA dispute settlement. We attribute this finding to two features of our experimental setting. First, most countries are in compliance with Montreal Protocol obligations. Because emissions targets are slack, the enforceability of provisions would also be slack, i.e. the threat of disputes under the RTA are not binding since most countries are not in violation of the provisions and/or the Montreal Protocol. Second, because the Montreal Protocol is a binding and enforceable international agreement, linking trade policy to it may not require enforceability of commitments via RTA dispute settlement channels since enforceability already binds under the Montreal Protocol.

Despite these findings, linking ODS and Montreal Protocol commitments to trade agreements with dispute settlement mechanisms that fall under the RTA might become more important in the future. Recent evidence suggests that China has increased production and consumption of

CFC-11—an Annex A prohibited substance (Rigby *et al.*, 2019). However, punitive measures in the Montreal Protocol are limited. Linking ODS commitments to potentially punitive trade policy via RTA dispute settlement channels may create opportunities to apply binding policy pressures on non-compliant Montreal Protocol members.

5 Concluding Remarks

The past 30 years have seen an unprecedented push for trade liberalization with 262 regional trade agreements (RTAs) involving 188 countries entering into force over this period. This coincides with the signing of the Montreal Protocol in 1987, a landmark international agreement that has achieved a near universal membership and is reported to have successfully prevented catastrophic damage to the planet's ozone layer.

While reducing trade barriers offers tremendous potential for economic growth and productivity gains, higher incomes and increased industrial output could challenge the gains achieved by the Montreal Protocol by increasing domestic use of CFC and other ozone depleting substances. Indeed, we find that trade liberalization increases consumption of Annex A gases—CFCs and halons. However, average deviation from Montreal Protocol targets remain negative, meaning RTAs "reduce overcompliance" to the Montreal Protocol. We find that environmental provisions prevent this reduction in overcompliance for CFCs and halons, suggesting that trade pressure and further technology transfer, most likely from developed to developing nations, helped countries phaseout CFCs and halons quicker.

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6 Tables and Figures

Table 1: Montreal Protocol Gases and Targets

Gas	Introduction	0% Date: nonArticle 5	0% Date: Article 5
	Annex A		
CFCs	Montreal Protocol (1987)	1996	2010
halons	Montreal Protocol (1987)	1994	2010
	Annex B		
"other" CFCs*	London Amendment (1990)	1996	2010
CTC	London Amendment (1990)	1996	2010
TCA	London Amendment (1990)	1996	2015
	Annex C		
HCFCs	Copenhagen Amendment (1992)	2020	2030
HBFCs	Copenhagen Amendment (1992)	1996	1996
BCM	Beijing Amendment (1999)	2002	2002
	Annex E		
MB	Copenhagen Amendment (1992)	2005	2015
	Annex F		
HFCs	Kigali Amendment (2016)	2036 (85%)	2045 (85%)

$*$ Other Fully Halogenated CFCs

Table 2: Deviation from Montreal Protocol Targets after RTA Signature

	Dependent variable: IHS Target Deviation						
	CFCs	Halons	CFCs (B)	CTC	TCA	HCFCs	MB
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post Sig	0.696***	0.371***	0.021	0.139	0.022	−0.396***	−0.024
	(0.154)	(0.094)	(0.039)	(0.102)	(0.052)	(0.083)	(0.106)
Post × ODS	−1.401***	−0.381**	−0.043	−0.434*	−0.287*	−0.005	0.023
	(0.381)	(0.190)	(0.078)	(0.251)	(0.170)	(0.212)	(0.280)
Observations	6,118	6,118	6,118	6,118	6,118	6,118	6,118
R^2	0.526	0.551	0.390	0.484	0.602	0.642	0.528
Mean (ODP tons)	-1402	-261	-3	-551	-30	-116	14

FE triple-difference regressions on a stacked country-level panel with a ±3 year event window around RTA signature. All outcomes are the inverse hyperbolic sine of the difference between ODS emissions and emissions targets under the Montreal Protocol. All models include country-event fixed effects. Robust standard errors are (two-way) clustered at the country-event and country-year levels. We report the mean deviation from target across the entire sample in tons of ozone depletion potential (ODP). Statistical significance from two-sided t tests are denoted by *p<0.1; **p<0.05; ***p<0.01.

Table 3: Deviation from Montreal Protocol Targets after RTA Signature

	Dependent variable: IHS Target Deviation						
	CFCs	Halons	CFCs (B)	CTC	TCA	HCFCs	MB
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post Sig	0.698***	0.370***	0.022	0.139	0.021	−0.393***	−0.028
	(0.154)	(0.094)	(0.039)	(0.103)	(0.052)	(0.083)	(0.106)
Post × ODS	−1.280***	−0.482**	0.093	−0.401	−0.319	0.322***	−0.406
	(0.370)	(0.220)	(0.127)	(0.274)	(0.231)	(0.100)	(0.462)
Post × ODS × Bind	−0.171	0.142	−0.191	−0.045	0.044	−0.460*	0.603
	(0.501)	(0.255)	(0.144)	(0.269)	(0.272)	(0.248)	(0.500)
Observations	6,118	6,118	6,118	6,118	6,118	6,118	6,118
R^2	0.527	0.551	0.390	0.484	0.602	0.643	0.528
Mean (ODP tons)	-1402	-261	-3	-551	-30	-116	14

FE triple-difference regressions on a stacked country-level panel with a ±3 year event window around RTA signature. All outcomes are the inverse hyperbolic sine of the difference between ODS emissions and emissions targets under the Montreal Protocol. Bind is an indicator equal to 1 if the the ODS provisions are binding with dispute settlement under the RTA. All models include country-event fixed effects. Robust standard errors are (two-way) clustered at the country-event and country-year levels. We report the mean deviation from target across the entire sample in tons of ozone depletion potential (ODP). Statistical significance from two-sided t tests are denoted by *p<0.1; **p<0.05; ***p<0.01.

Figure 1: Regional Trade Agreements and ODS Provisions over Time

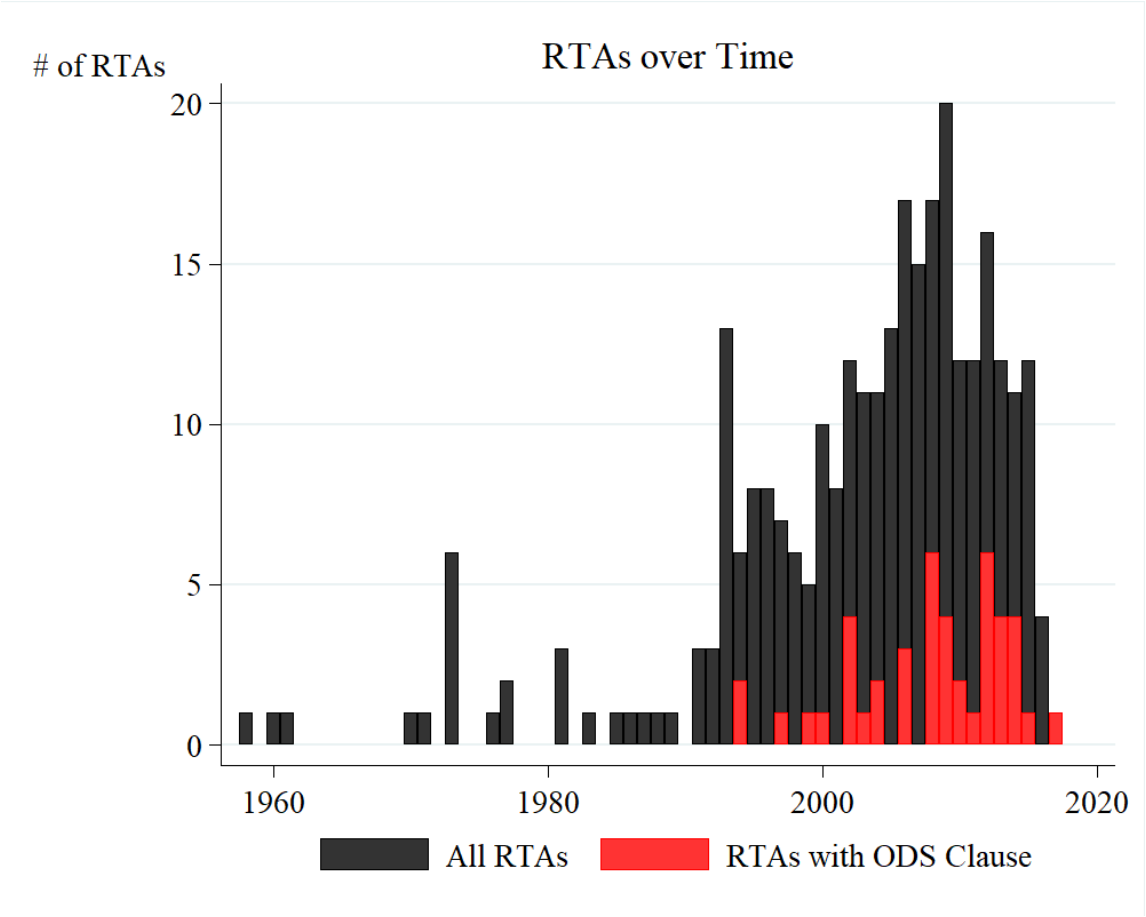


Figure 2: ODS Provisions and non-Article 5 Phaseout Schedules

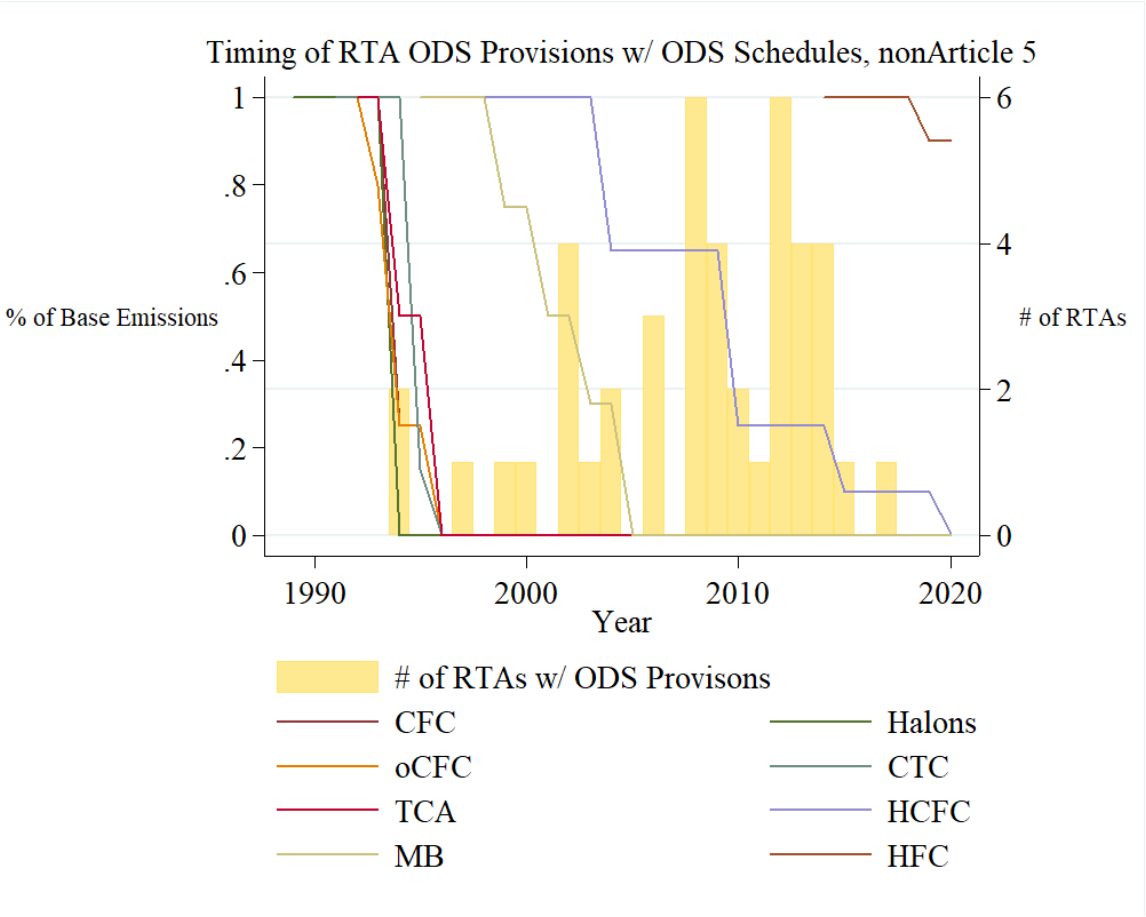


Figure 3: ODS Provisions and Article 5 Phaseout Schedules

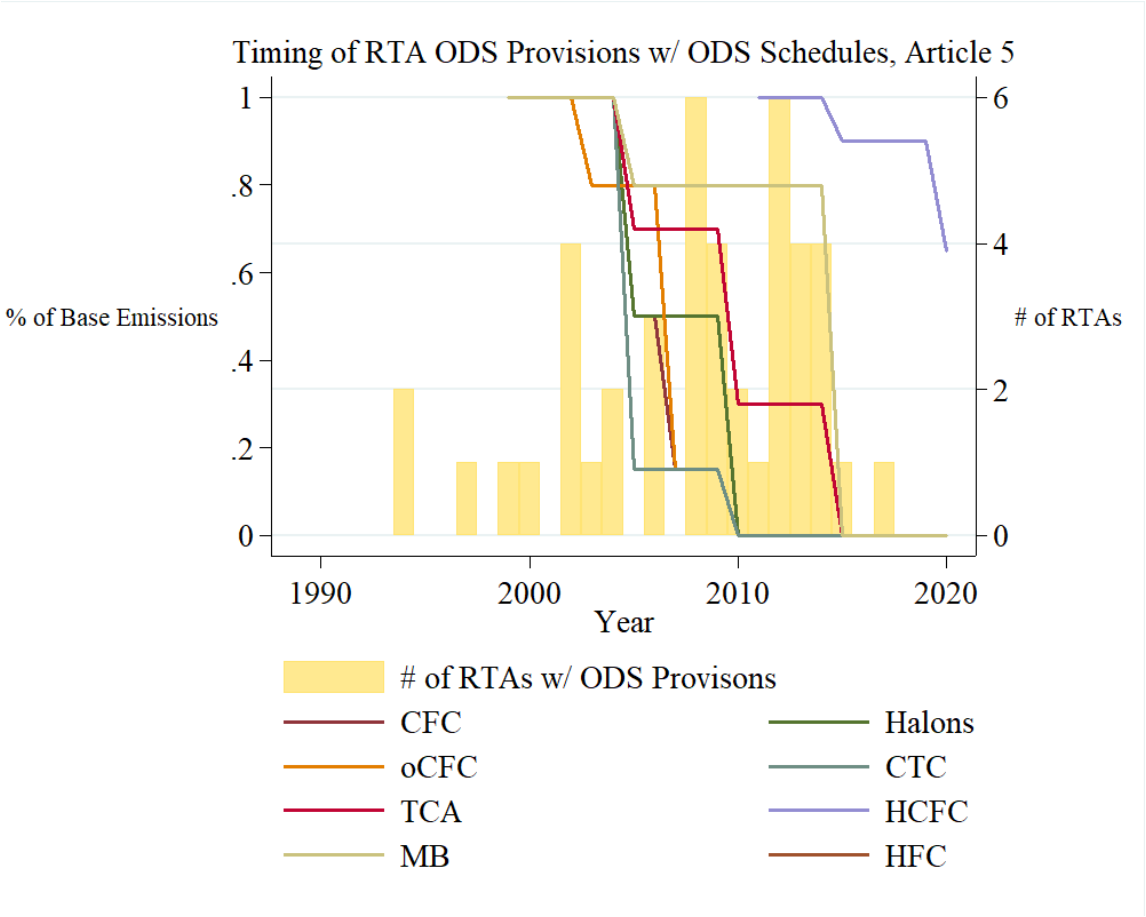


Figure 4: Timing of ODS Provisions and Phaseout Schedules

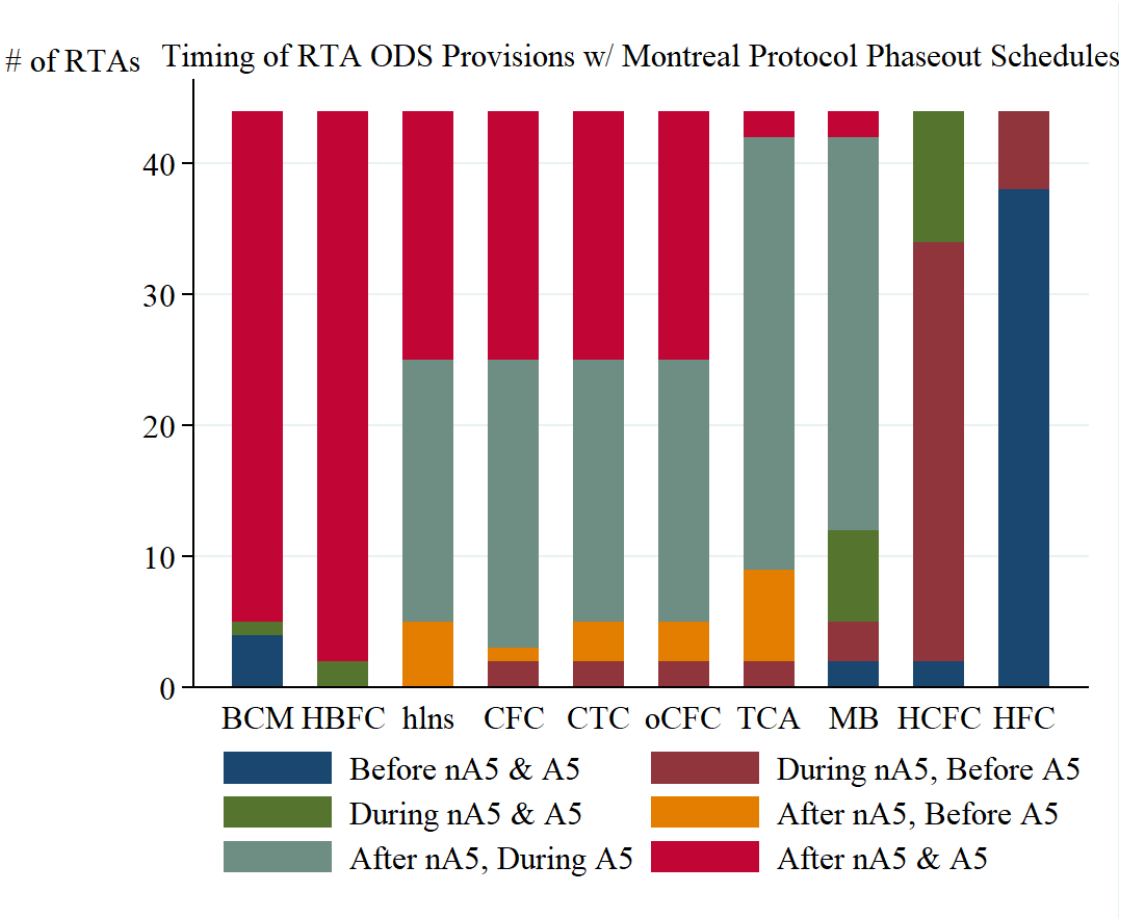


Figure 5: CFC Event Study Around Signature of RTA

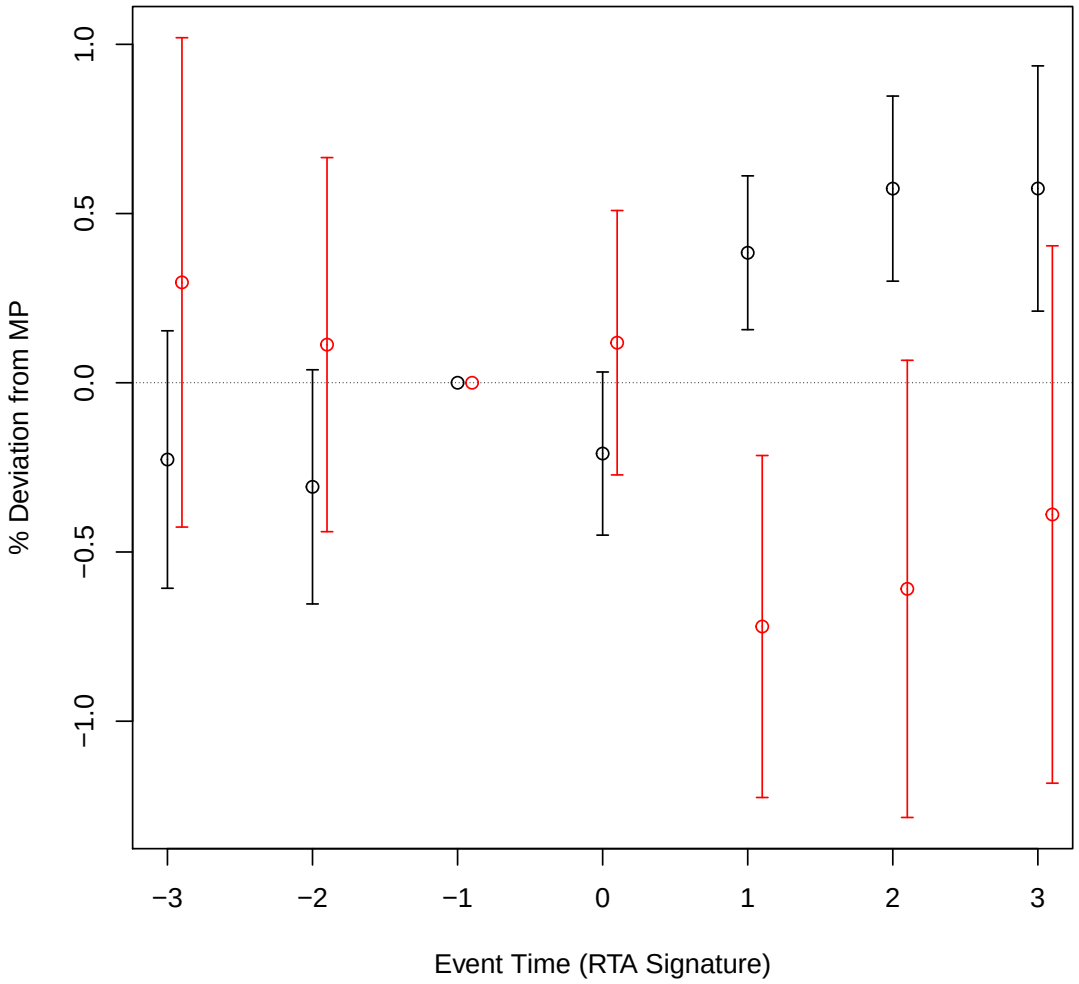


Figure 6: Halon Event Study Around Signature of RTA

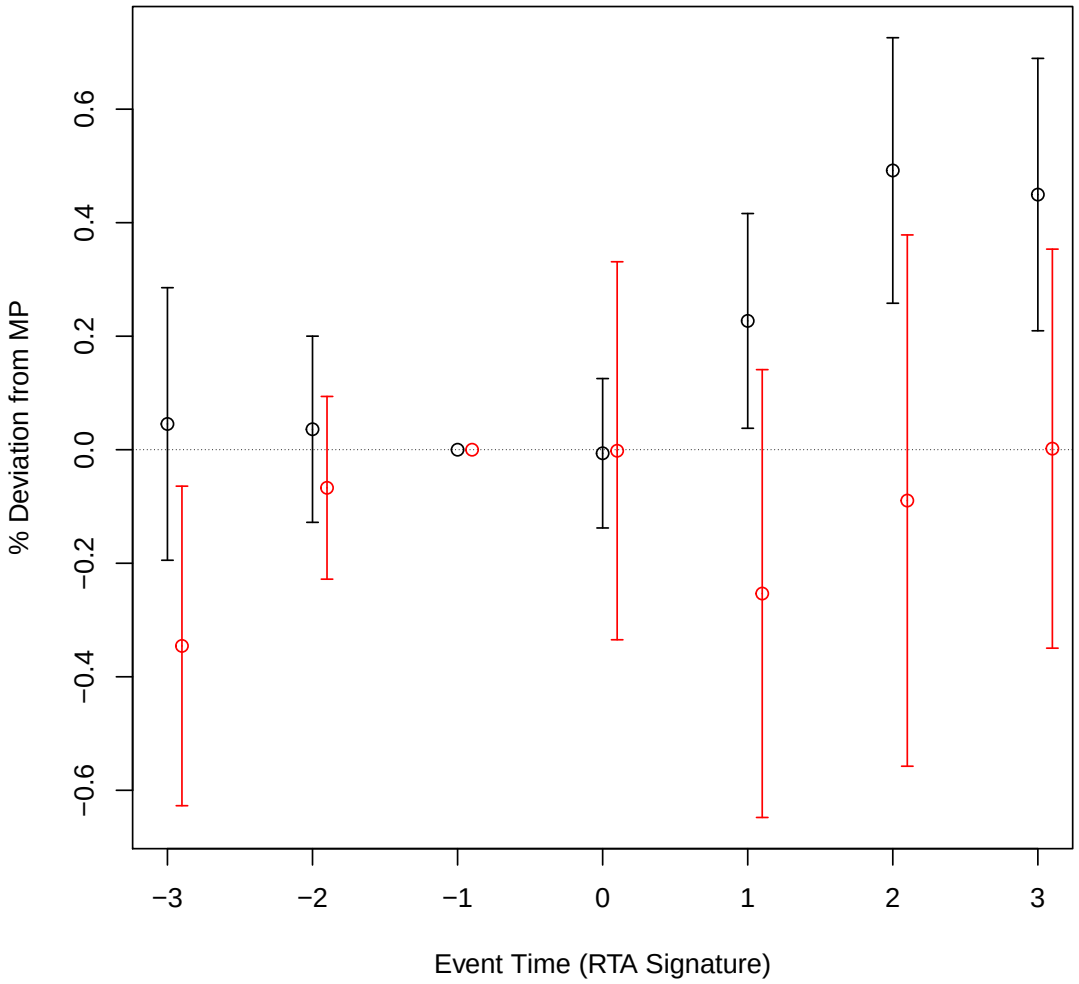


Figure 7: Annex B CFC Event Study Around Signature of RTA

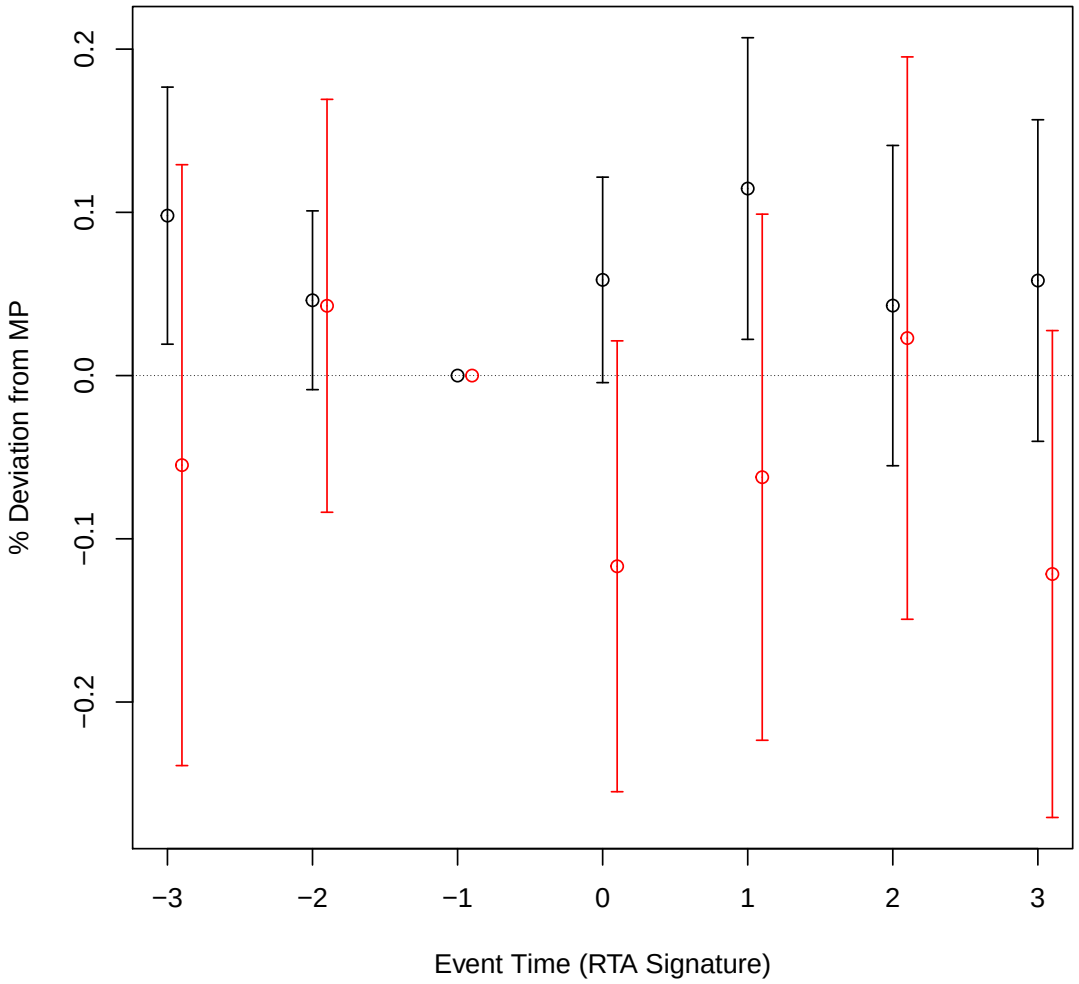


Figure 8: CTC Event Study Around Signature of RTA

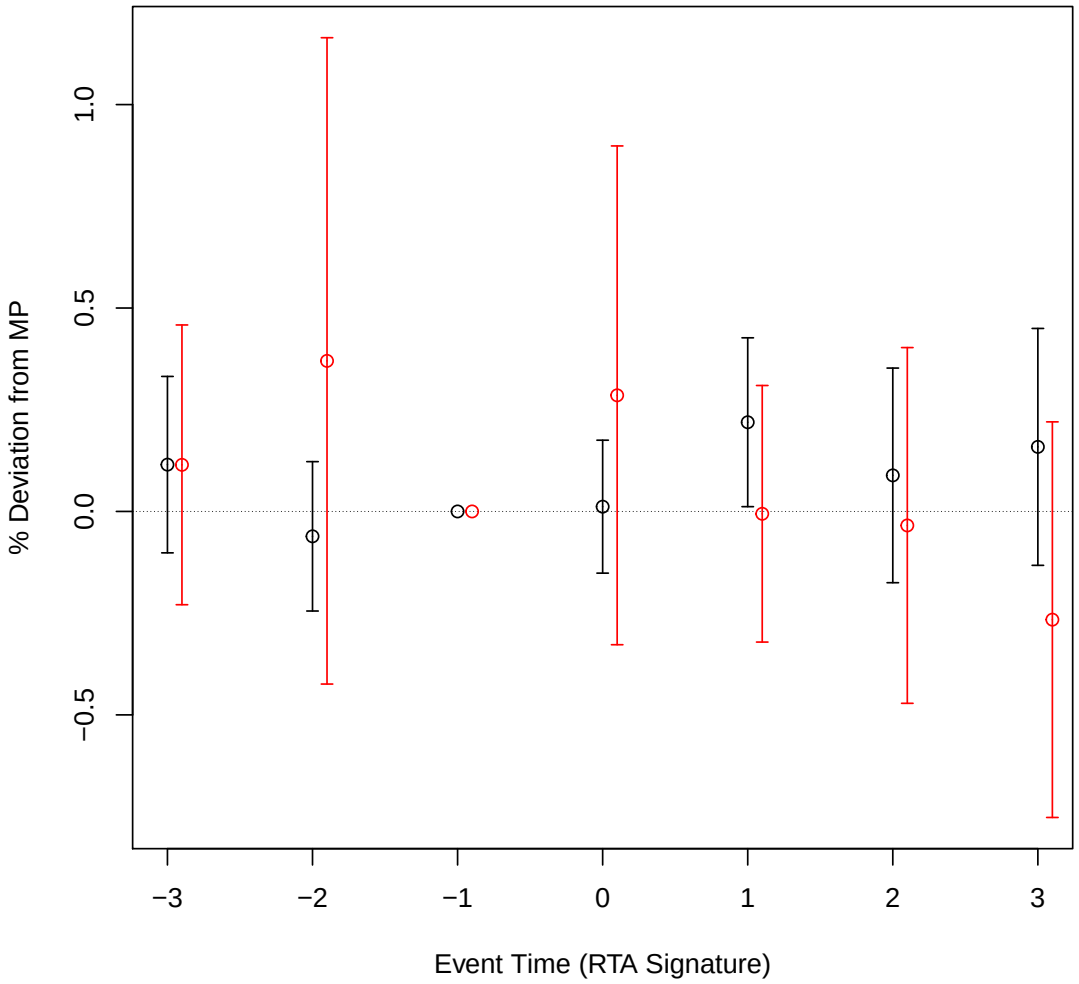


Figure 9: TCA Event Study Around Signature of RTA

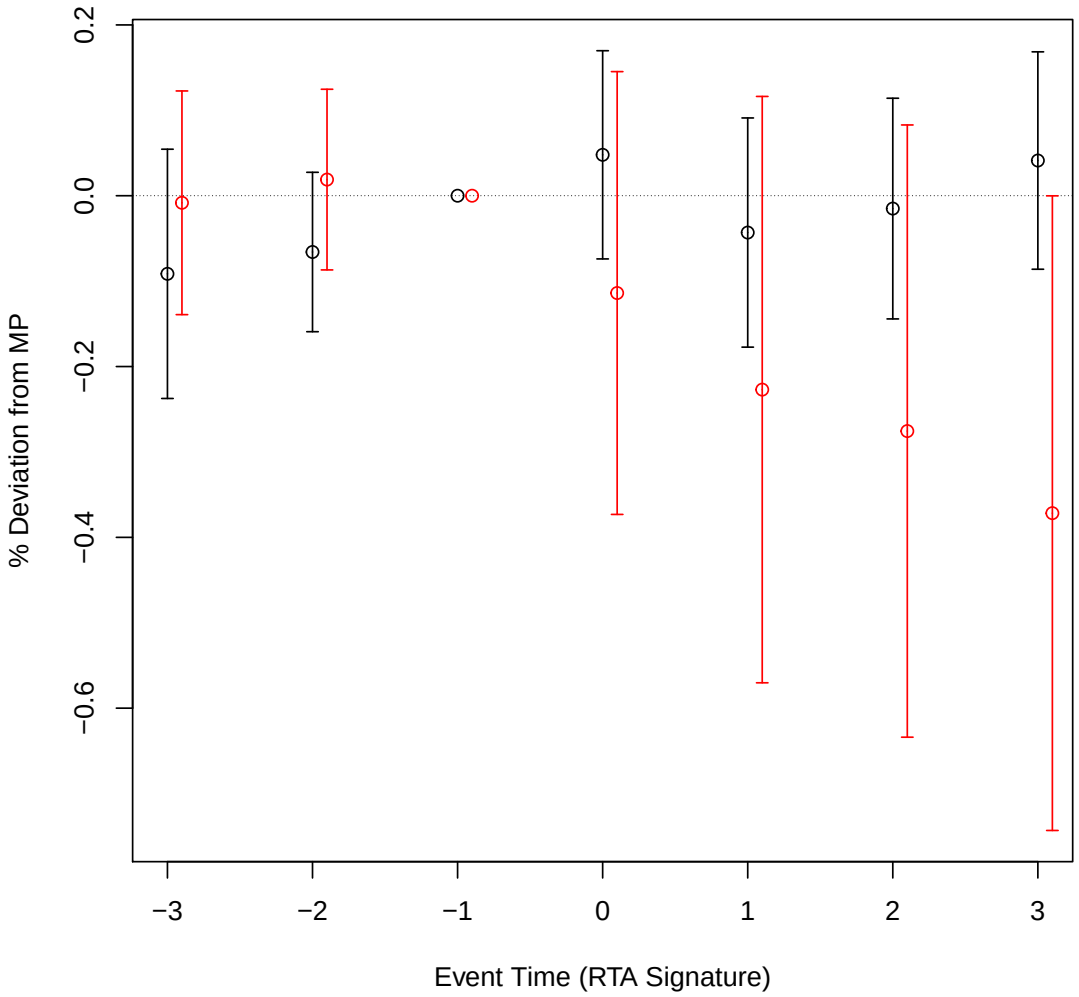


Figure 10: HCFC Event Study Around Signature of RTA

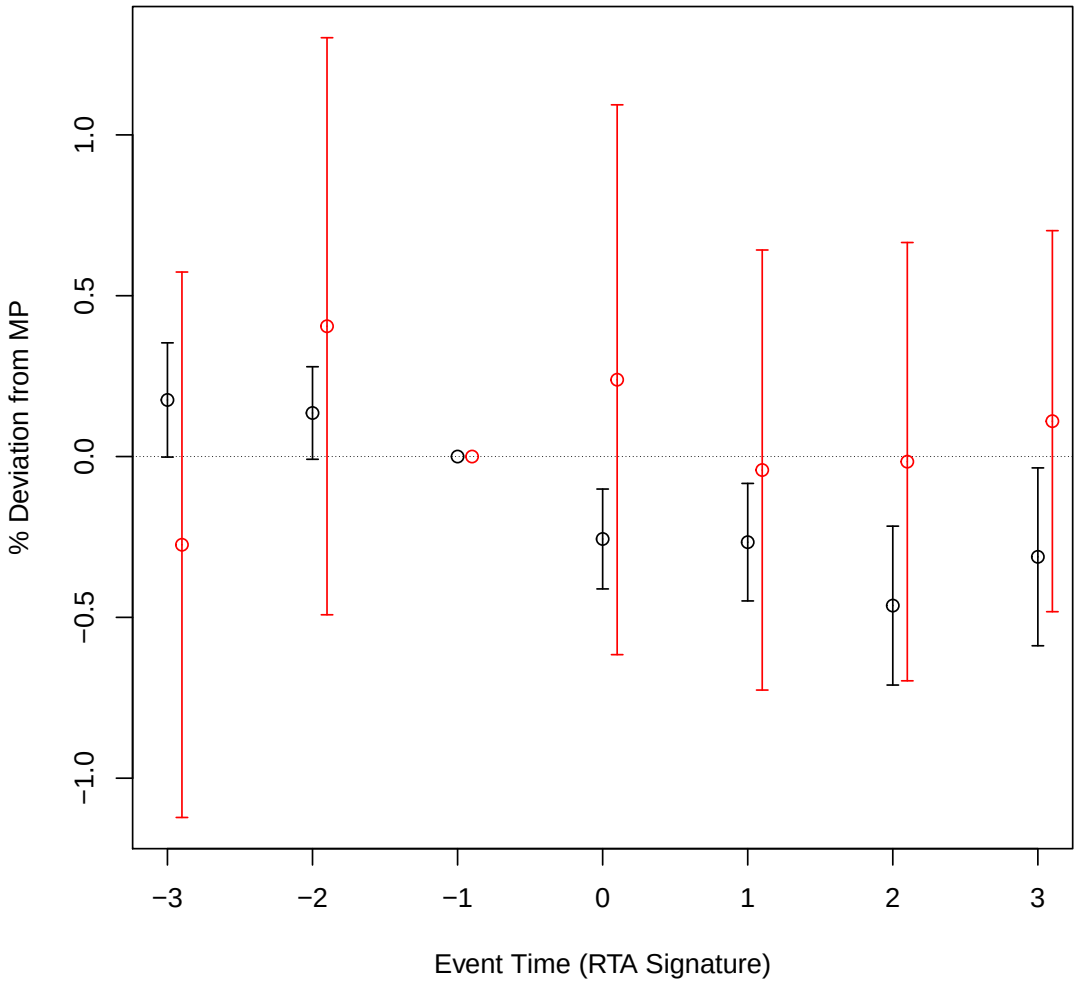
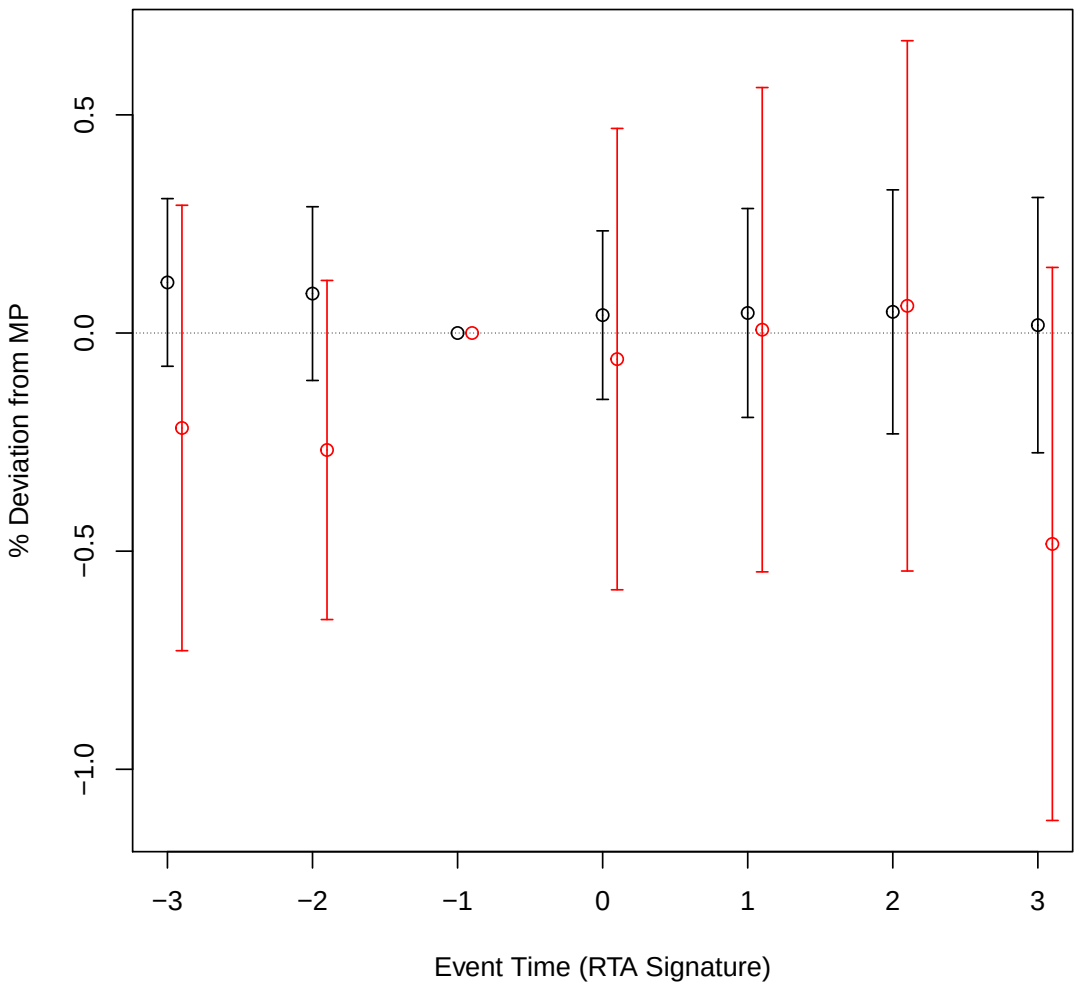


Figure 11: Methyl Bromide Event Study Around Signature of RTA



A Appendix: Supplemental Tables and Figures

Table A.1: Regional Trade Agreements with ODS Provisions

Agreement	Entry into Force	Supplemental Dispute Settlement
Common Market for Eastern and Southern Africa (COMESA)	1994	0
North American Free Trade Agreement (NAFTA)	1994	1
Canada - Chile	1997	1
Chile - Mexico	1999	1
East African Community (EAC)	2000	1
EU - San Marino	2002	0
Chile - El Salvador (Chile - Central America)	2002	1
Canada - Costa Rica	2002	1
Chile - Costa Rica (Chile - Central America)	2002	0
Panama - El Salvador (Panama - Central America)	2003	1
US - Chile	2004	1
Panama - Chinese Taipei	2004	1
US - Bahrain	2006	1
Japan - Malaysia	2006	1
Guatemala - Chinese Taipei	2006	1
EU - Bosnia and Herzegovina	2008	0
EU - Montenegro	2008	0
El Salvador - Honduras - Chinese Taipei	2008	1
Chile - Honduras (Chile - Central America)	2008	1
Nicaragua - Chinese Taipei	2008	1
Panama - Costa Rica (Panama - Central America)	2008	1
Panama - Guatemala (Panama - Central America)	2009	0
Canada - Peru	2009	1
US - Peru	2009	1
Panama - Honduras (Panama - Central America)	2009	1
Chile - Guatemala (Chile - Central America)	2010	1
EU - Serbia	2010	0
Canada - Colombia	2011	1
Korea, Republic of - US	2012	1
US - Colombia	2012	1
Canada - Jordan	2012	1
US - Panama	2012	1
Chile - Malaysia	2012	1
Chile - Nicaragua (Chile - Central America)	2012	1
Canada - Panama	2013	1
EU - Central America	2013	1
New Zealand - Chinese Taipei	2013	0
EU - Colombia and Peru	2013	1
EU - Ukraine	2014	1
EU - Georgia	2014	1
EU - Rep. of Moldova	2014	1
Canada - Honduras	2014	1
Canada - Korea, Republic of	2015	1
Trans-Pacific Partnership	2017	1

Figure A.1: Montreal Protocol and London Amendment Ratification

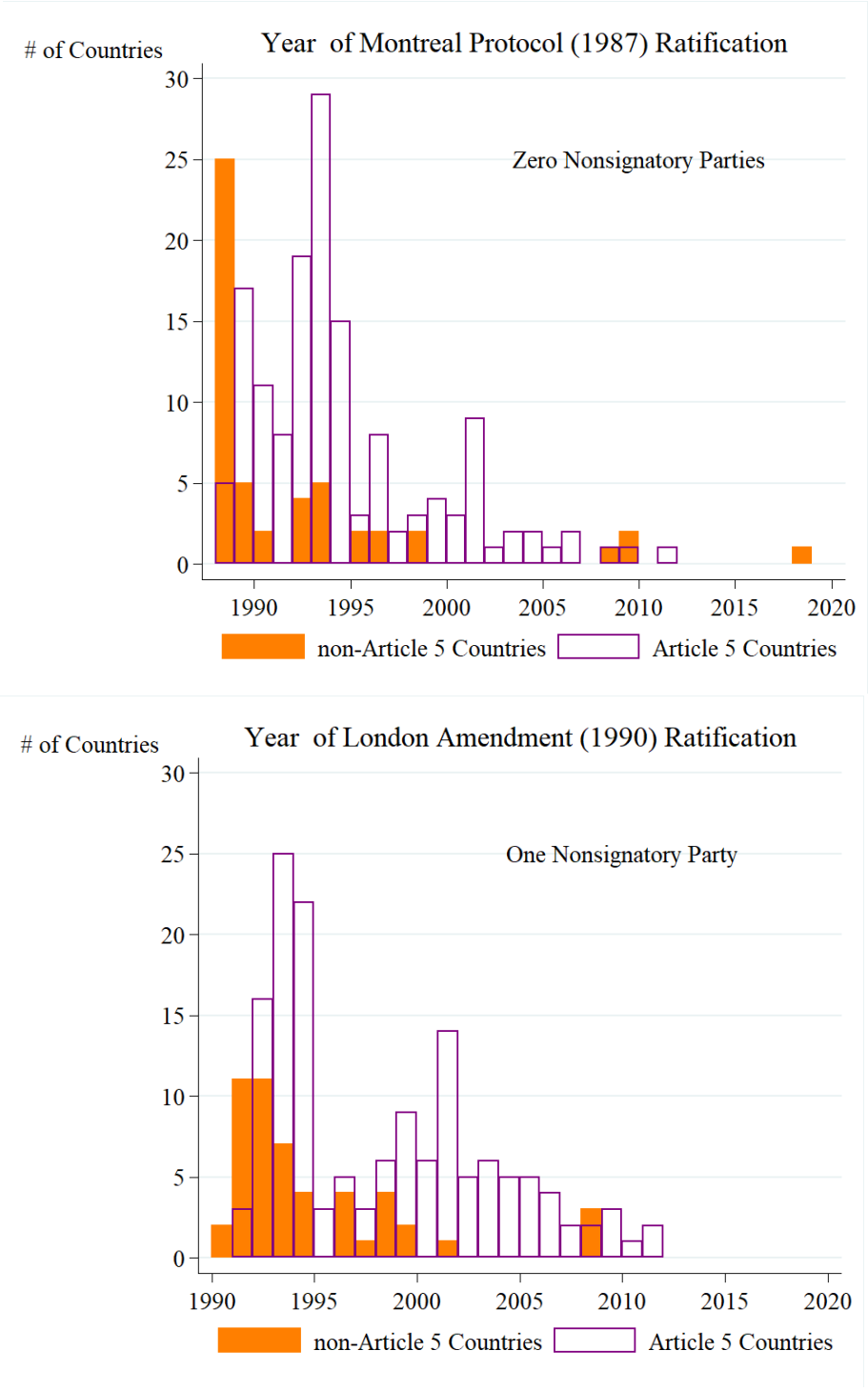


Figure A.2: Copenhagen Amendment and Montreal Amendment Ratification

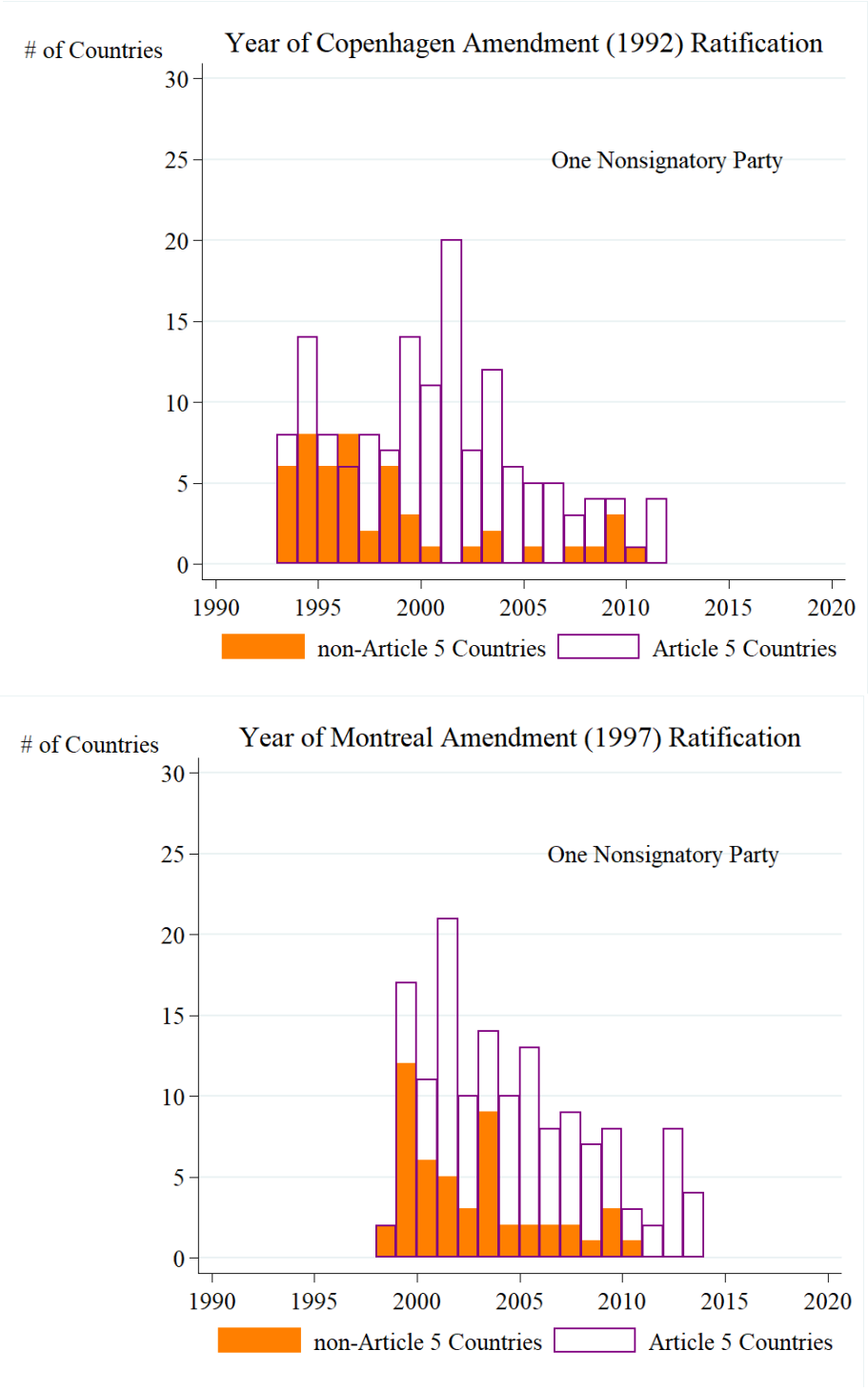


Figure A.3: Beijing Amendment and Kigali Amendment Ratification

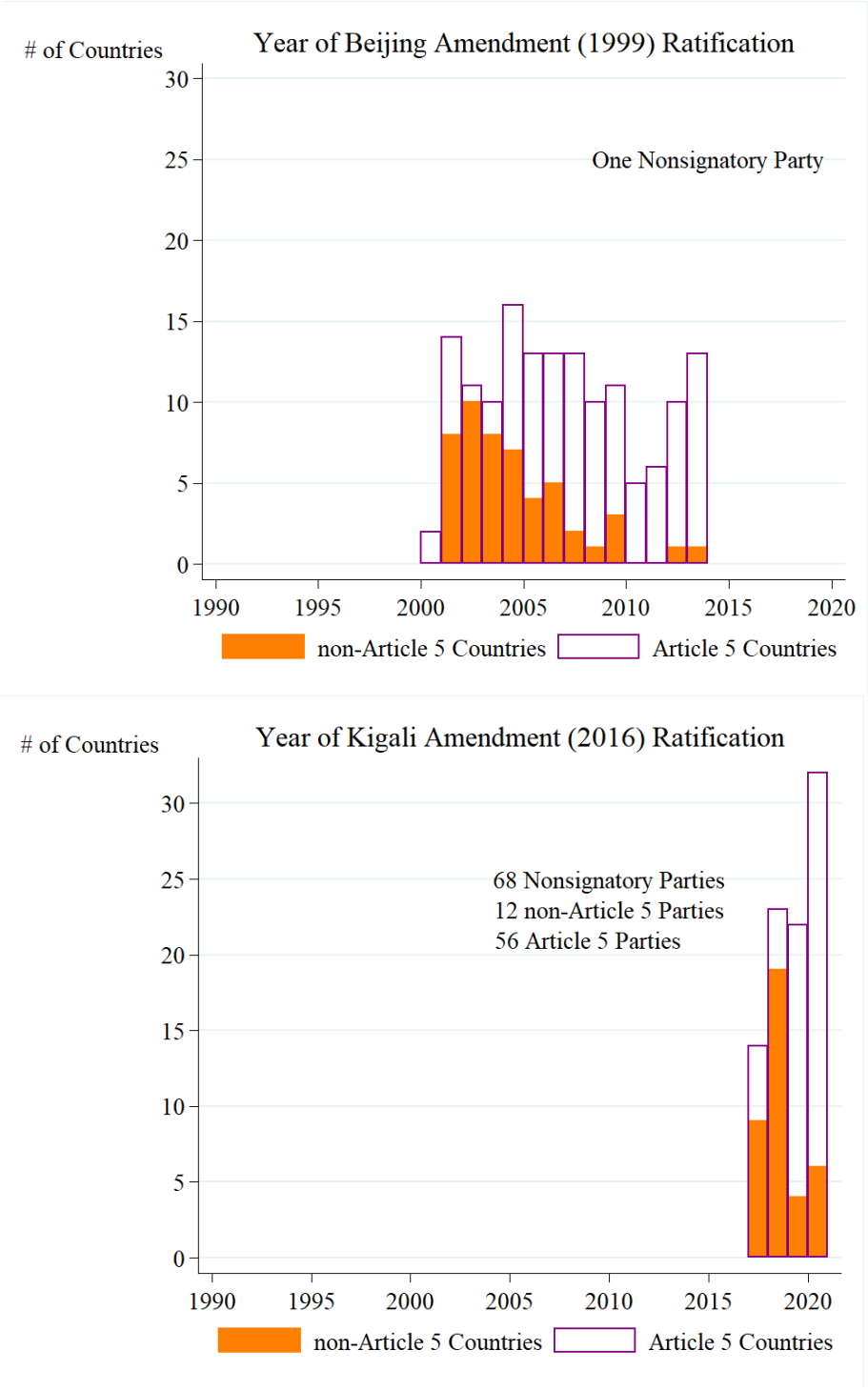


Table A.2: Deviation from Montreal Protocol Targets after Entry into Force of RTA

	Dependent variable: IHS Target Deviation						
	CFCs	Halons	CFCs (B)	CTC	TCA	HCFCs	MB
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post RTA	0.475***	0.347***	0.016	0.115	0.028	−0.403***	0.023
	(0.141)	(0.096)	(0.031)	(0.075)	(0.050)	(0.088)	(0.094)
Post × ODS	−0.220	−0.267*	−0.042	−0.241	0.162	−0.134	−0.096
	(0.295)	(0.147)	(0.069)	(0.200)	(0.118)	(0.201)	(0.236)
Observations	6,118	6,118	6,118	6,118	6,118	6,118	6,118
R^2	0.562	0.579	0.408	0.485	0.661	0.645	0.566
Mean (ODP tons)	-821	-218	-3	-472	-19	-128	10

FE triple-difference regressions on a stacked country-level panel with a ±3 year event window around RTA entry into force. All outcomes are the inverse hyperbolic sine of the difference between ODS emissions and emissions targets under the Montreal Protocol. All models include country-event fixed effects. Robust standard errors are (two-way) clustered at the country-event and country-year levels. We report the mean deviation from target across the entire sample in tons of ozone depletion potential (ODP). Statistical significance from two-sided t tests are denoted by *p<0.1; **p<0.05; ***p<0.01.

Table A.3: Deviation from Montreal Protocol Targets after Entry into Force of RTA

	Dependent variable: IHS Target Deviation						
	CFCs	Halons	CFCs (B)	CTC	TCA	HCFCs	MB
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post RTA	0.472***	0.345***	0.014	0.118	0.027	−0.401***	0.022
	(0.141)	(0.096)	(0.031)	(0.075)	(0.050)	(0.088)	(0.094)
Post × ODS	−0.528*	−0.458***	−0.258	0.103	0.025	0.126	−0.178
	(0.290)	(0.159)	(0.164)	(0.228)	(0.055)	(0.222)	(0.475)
Post × ODS × Bind	0.434	0.269	0.304*	−0.484	0.193	−0.367	0.114
	(0.399)	(0.182)	(0.170)	(0.298)	(0.133)	(0.291)	(0.492)
Observations	6,118	6,118	6,118	6,118	6,118	6,118	6,118
R^2	0.562	0.579	0.409	0.485	0.661	0.645	0.566
Mean (ODP tons)	-821	-218	-3	-472	-19	-128	10

FE triple-difference regressions on a stacked country-level panel with a ±3 year event window around RTA entry into force. All outcomes are the inverse hyperbolic sine of the difference between ODS emissions and emissions targets under the Montreal Protocol. Bind is an indicator equal to 1 if the the ODS provisions are binding with dispute settlement under the RTA. All models include country-event fixed effects. Robust standard errors are (two-way) clustered at the country-event and country-year levels. We report the mean deviation from target across the entire sample in tons of ozone depletion potential (ODP). Statistical significance from two-sided t tests are denoted by *p<0.1; **p<0.05; ***p<0.01.

Table A.4: Montreal Protocol Parties

Party	**Article 5?**	**Party**	**Article 5?**	**Party**	**Article 5?**
Afghanistan	Yes	Costa Rica	Yes	India	Yes
Albania	Yes	Croatia	No	Indonesia	Yes
Algeria	Yes	Cuba	Yes	Iran	Yes
Andorra	No	Cyprus	No	Iraq	Yes
Angola	Yes	Czech Republic	No	Ireland	No
Antigua and Barbuda	Yes	Côte d'Ivoire	Yes	Israel	No
Argentina	Yes	North Korea	Yes	Italy	No
Armenia	Yes	Dem. Rep. of Congo	Yes	Jamaica	Yes
Australia	No	Denmark	No	Japan	No
Austria	No	Djibouti	Yes	Jordan	Yes
Azerbaijan	No	Dominica	Yes	Kazakhstan	No
Bahamas	Yes	Dominican Republic	Yes	Kenya	Yes
Bahrain	Yes	Ecuador	Yes	Kiribati	Yes
Bangladesh	Yes	Egypt	Yes	Kuwait	Yes
Barbados	Yes	El Salvador	Yes	Kyrgyzstan	Yes
Belarus	No	Equatorial Guinea	Yes	Laos	Yes
Belgium	No	Eritrea	Yes	Latvia	No
Belize	Yes	Estonia	No	Lebanon	Yes
Benin	Yes	Eswatini	Yes	Lesotho	Yes
Bhutan	Yes	Ethiopia	Yes	Liberia	Yes
Bolivia	Yes	European Union	No	Libya	Yes
Bosnia and Herzegovina	Yes	Fiji	Yes	Liechtenstein	No
Botswana	Yes	Finland	No	Lithuania	No
Brazil	Yes	France	No	Luxembourg	No
Brunei Darussalam	Yes	Gabon	Yes	Madagascar	Yes
Bulgaria	No	Gambia	Yes	Malawi	Yes
Burkina Faso	Yes	Georgia	Yes	Malaysia	Yes
Burundi	Yes	Germany	No	Maldives	Yes
Cabo Verde	Yes	Ghana	Yes	Mali	Yes
Cambodia	Yes	Greece	No	Malta	No
Cameroon	Yes	Grenada	Yes	Marshall Islands	Yes
Canada	No	Guatemala	Yes	Mauritania	Yes
Cent. African Republic	Yes	Guinea	Yes	Mauritius	Yes
Chad	Yes	Guinea Bissau	Yes	Mexico	Yes
Chile	Yes	Guyana	Yes	Micronesia	Yes
China	Yes	Haiti	Yes	Monaco	No
Colombia	Yes	Holy See	No	Mongolia	Yes
Comoros	Yes	Honduras	Yes	Montenegro	Yes
Congo	Yes	Hungary	No	Morocco	Yes
Cook Islands	Yes	Iceland	No	Mozambique	Yes

Party	Article 5?	Party	Article 5?
Myanmar	Yes	Slovakia	No
Namibia	Yes	Slovenia	No
Nauru	Yes	Solomon Islands	Yes
Nepal	Yes	Somalia	Yes
Netherlands	No	South Africa	Yes
New Zealand	No	South Sudan	Yes
Nicaragua	Yes	Spain	No
Niger	Yes	Sri Lanka	Yes
Nigeria	Yes	State of Palestine	No
Niue	Yes	Sudan	Yes
North Macedonia	Yes	Suriname	Yes
Norway	No	Sweden	No
Oman	Yes	Switzerland	No
Pakistan	Yes	Syrian Arab Republic	Yes
Palau	Yes	Tajikistan	No
Panama	Yes	Thailand	Yes
Papua New Guinea	Yes	Timor-Leste	Yes
Paraguay	Yes	Togo	Yes
Peru	Yes	Tonga	Yes
Philippines	Yes	Trinidad and Tobago	Yes
Poland	No	Tunisia	Yes
Portugal	No	Turkey	Yes
Qatar	Yes	Turkmenistan	Yes
Republic of Korea	Yes	Tuvalu	Yes
Republic of Moldova	Yes	Uganda	Yes
Romania	No	Ukraine	No
Russian Federation	No	United Arab Emirates	Yes
Rwanda	Yes	United Kingdom	No
Saint Kitts and Nevis	Yes	United Republic of Tanzania	Yes
Saint Lucia	Yes	United States of America	No
Saint Vincent and the Grenadines	Yes	Uruguay	Yes
Samoa	Yes	Uzbekistan	No
San Marino	No	Vanuatu	Yes
Sao Tome and Principe	Yes	Venezuela (Bolivarian Republic of)	Yes
Saudi Arabia	Yes	Vietnam	Yes
Senegal	Yes	Yemen	Yes
Serbia	Yes	Zambia	Yes
Seychelles	Yes	Zimbabwe	Yes
Sierra Leone	Yes		
Singapore	Yes		