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Negative Carbon Leakage: Evidence from South Asian Countries

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Contents

Abstract

We test the ‘Carbon Leakage Hypothesis’ using the gravity model for three South Asian countries, India, Pakistan and Sri Lanka. The analytical model captures the interaction between the sectoral carbon emission intensity of the selected commodities and the climate policy adopted by the trading partners of the three South Asian economies. This interaction variable determines the destination of export of high carbon intensive goods versus low carbon intensive goods, i.e., whether the destination is Kyoto-binding countries or not. We use data on the export of 18 selected commodities over the period of 2000-2012 to gauge the impact of the Kyoto Protocol on the export of carbon-intensive goods. We find evidence of negative carbon leakage in the case of goods exported from India and Sri Lanka as well as for the combined exports from the three countries while some evidence exists of positive carbon leakage for goods from Pakistan. The study also finds that, whether positive or negative, the carbon leakage effect is commodity specific.

Keywords

Carbon leakage, Kyoto Protocol, carbon intensity, gravity model, South Asia

JEL Classification: F18, Q54, Q58

Negative Carbon Leakage: Evidence from South Asian Countries

1. Introduction

The Kyoto Protocol, which was based on the common but differentiated responsibility and respective capabilities principle of the United Nations Framework Convention on Climate Change (UNFCCC), is generally considered environmentally ineffective (Peters *et al.*, 2011) and inadequate. The concept of 'carbon leakage', i.e., increased trade in carbon intensive products and services from developing to developed countries, is a major reason cited for the perceived ineffectiveness of the Protocol since the carbon commitments apply to production activities of only the Kyoto-binding countries. The Technical Summary of the Intergovernmental Panel on Climate Change Assessment Report 5, Working Group III (2014) reports that a growing share of CO_2 emissions from fossil fuel combustion in middle-income countries is released in connection with the production of goods and services that are exported, notably, from upper middle-income countries to high-income countries. Despite this claim, the gap between production- and consumption-based emissions has been almost constant over time although the total emissions show an increase in the case of lower middle-income countries like India (IPCC WG III, 2014). Since the available evidence does not support the hypothesis of carbon leakage from these countries, it is imperative that researchers empirically evaluate the Carbon Leakage Hypothesis using available data on exports from these countries.

Carbon leakage represents a specific instance of the Pollution Haven Hypothesis.[3] The Hypothesis describes a composition effect wherein a country with a comparative advantage in terms of the environmental regulations in place (i.e., weak environmental regulations) would export pollution intensive goods to countries with a comparative disadvantage in terms of environmental regulations (i.e. stronger environmental regulations) (Antweiler *et al.* 2001; Frankel, 2005). Carbon leakage is related to this concept of comparative advantage. It can be positive or negative depending on the pattern of trade-induced specialization.

According to Grossman and Krueger (1993), a unilateral carbon or environmental policy results in regulatory differences between trading partners such that abatement efforts in one country is expected to be offset by the increased pollution levels in the other country. Such a policy may cause carbon leakage through two routes: (i) polluting industries may migrate from Kyoto-binding countries to non-participating countries, which involves a geographical shift in production in response to climate policy; and (ii) consumption in a participating country is met by increased production in a non-participating country (Peters and Hertwich, 2008). We intend to examine leakage via the latter route in the case of three South Asian countries.

Much of the empirical literature on carbon leakage employs computable general equilibrium (CGE) modeling to compute the ex-ante effects of the Kyoto Protocol on the extent of the leakage and the competitiveness of trading partners (He *et al.* 2009; Babiker, 2005; Elliott *et al.* 2010; Monjon and Quirion, 2011; Mathiesen and Moestad, 2004).[4] But, as the IPCC Working Group III (2014) reports, the range in estimations, which varies from a very moderate 5 percent to as large as 130 percent, is large with high uncertainties. However, most of these studies

[3] On Pollution Haven Hypothesis, see Ederington and Minier (2003); Ederington *et al.* (2005); Levinson and Taylor (2008); and the survey article by Brunnermeier and Levinson (2004).

[4] For example, see Felder and Rutherford (1993); Bernstein *et al.* (1999); Burniaux and Martins (2000); Babiker (2005); Elliott *et al.* (2010).

have found positive carbon leakage ranging between 5 and 20 percent (Bucher and Schenker, 2011). In contrast, ex-post studies making econometric estimations of the leakage are very scant[5]. These studies use the gravity model of trade to measure the extent of leakages due to the Kyoto Protocol. However, most such empirical studies are limited to either the broader trade blocks, involving mostly the developed countries, or to the trade relationship between US and China. Böhringer and Rutherford (2000), for instance, analyze the process of carbon leakage against a theoretical background of international trade and find that the choice of assumptions has a large impact on the rate of leakage: the larger the trade elasticities (the more homogeneous the goods), the larger the rate of leakage. This result is in conformity with Bollen *et al.* (2000) where they conducted a sensitivity analysis on trade and substitution elasticities. We analyze instead evidence from South Asian countries, particularly India, Pakistan and Sri Lanka, three countries that are not bound by the Kyoto commitments and are, in addition, lower middle-income countries.

Against the many studies that observe positive leakage, only a few studies have observed negative leakage, among them, Felder and Rutherford (1993) who, using the CGE model, observed negative leakage after several decades if the carbon tax leaves enough unused oil to delay the other region's switch to carbon intensive synthetic fuel. Negative leakage is also possible due to endogeneity of climate policy (Copeland and Taylor, 2005); technological diffusion (Grubb *et al.* 2002; Gerlagh and Kuik, 2014); or changes in wage-rental ratio (Chua, 2003; Karp, 2013). But negative leakage is possible even in the absence of such factors (Baylis *et al.* 2014). The possibility is based on three general assumptions. Firstly, the domestic and imported goods are not perfect substitutes. Therefore, consumers can still cause leakage when they substitute towards the imported good though not perfectly. Secondly, the elasticity of substitution in production is not zero; firms reduce the carbon per unit of output by using an abatement resource where the firm has some ability to substitute out of carbon and into clean input. Thirdly, the clean input is mobile between the trading partners so that a country with a unilateral climate policy gets clean resources from a country without a climate policy as a result of which the leakage is negative. Baylis *et al.* (2014) has termed it the 'abatement resource effect'.

Thus, the existing literature offers little ex-post evidence on the effects of climate change policies on trade and leakage. The World Bank (2008), which employs a gravity framework to test the effects of carbon taxes on bilateral trade in goods, concludes that there is no evidence of carbon leakage. In contrast, Aichele and Felbermayr (2015) use the structural version of the gravity model and conclude that the binding commitments under Kyoto have increased the embodied carbon imports of the committed countries by around 8 percent and the emission intensity of their imports from non-committed countries by roughly 3 percent. Correspondingly, Sato and Dechezleprêtre (2015), using the gravity model, have found that a 10% increase in the energy price difference between two country sectors increases imports only by 0.2%.

A survey of related studies reveals that those on the ex-ante effects of unilateral climate policies use the CGE modeling approach and that the extent and direction of carbon leakage depend on assumptions in the modeling. Ex-post evaluations using econometric approaches, on the other hand, are few and evidence of carbon leakage inconclusive. Our study complements the existing literature on the Carbon Leakage Hypothesis. Previous studies have used OLS for the estimation of the gravity model and suffered from certain econometric problems such as heteroscedasticity and estimates that are not robust and consistent. To deal with these issues, Santos Silva and Tenreyro (2006) have proposed the Poisson PseudoMaximum Likelihood (PPML) estimator. Through the estimation of trade flows in levels, the PPML methodology allows for zero trade flows in the estimation process and provides heteroscedasticity-corrected estimates contrary to the log linear estimation of the gravity model using OLS. Through the Monte Carlo simulations, Martinez-Zarzoso (2013) however finds that though PPML is less affected by heteroscedasticity, the performance of PPML in terms of bias and standard errors is no different than the other estimators. She, therefore, recommends that the selection of the estimator should be based on appropriate statistical tests.

In our study, we therefore use the standard gravity model but estimate it using both OLS and PPML estimators and employ the regression error specification test (RESET) in order to select the appropriate model. We use the

[5] Among the available studies are World Bank (2008) and Aichele and Felbermayr (2013, 2015).

standard gravity model of bilateral trade to gauge the effect of Kyoto Protocol ratification by trading partners on the export of selected commodities from three South Asian countries, namely, India, Pakistan and Sri Lanka. By focusing on commodity (sector) specific exports[6] and their carbon intensity, the study avoids the potential problem of heterogeneity that arises due to the pooling of heterogeneous sectors (Levinson and Taylor, 2008; Jeppensen *et al.* 2002).

The results indicate negative carbon leakage from South Asian countries to the Kyoto-binding countries though the extent of leakage varies across commodities. This finding is contrary to the findings of most empirical studies that have been undertaken using trade flows between developed and developing countries (e.g. Aichele and Felbermayr, 2015; Demailly and Quirion, 2008). The evidence of negative carbon leakage from these South Asian countries suggests that the concerns regarding carbon leakage should not be the basis of climate and trade policies. The theoretical explanations for negative carbon leakage may be found in 'environmentally benign technological diffusion' (Gerlagh and Kuik, 2014), 'abatement resource effect' (Baylis *et al.* 2014) and effective variation in energy prices across countries (Sato and Dechezleprêtre, 2015). However we leave it to future research to explain the reason for negative carbon leakage in the case of the South Asian countries that we study.

The rest of the paper is organized as follows: Section 2 describes the empirical framework while Section 3 analyzes the data. Section 4 discusses the results of the gravity model and Section 5 presents the conclusions and policy implications arising from the study.

2. Empirical Framework

We follow Mulatu and Wossink (2014) in conceptualizing our empirical model.[7] Ratification of the Kyoto Protocol by a country implies that the country has stringent carbon regulation in comparison to its non-Kyoto-binding trading partners, which may lead to the import of carbon-intensive commodities from the non-binding countries by the country bound by the Protocol. However, a Kyoto-binding country cannot import all the carbon intensive commodities in unlimited quantities. Therefore, the carbon leakage depends on the interaction between carbon intensity and carbon regulation in a Kyoto-binding country and the interaction between regulation and sectoral carbon intensity in a non-Kyoto binding country.

We use the gravity model of trade to gauge the effect of Kyoto Protocol ratification by Annex B countries[8] on the exports of carbon intensive commodities from three South Asian countries—India, Pakistan and Sri Lanka. Accordingly, we specify our econometric model as follows:

$$\begin{aligned} X_{ijkt} &= \\ &exp[a + \alpha_1 \ln(y_{it}) + \alpha_2 \ln(y_{jt}) + \alpha_3 (Z_{ij}) + \alpha_4 (KyotoR_{jt} \times carbon\ intensity_{ijkt}) + \\ &\alpha_5 (KyotoR_{jt}) + \alpha_6 (K_{it}) + \alpha_7 (K_{jt}) + \alpha_8 (Fac_{ijt}) + \alpha_9 (MR_i) + \alpha_{10} (MR_j) + \\ &year_{dummy} + (Commodity_{dummy} \times MR_i) + (Commodity_{dummy}) \times MR_j) + v_{ij}]\ \varepsilon_{ijt} \end{aligned} \quad (1)$$

where X_{ijkt} represents the exports from country i to j for the commodity k at time t; y_i and y_j are the GDP of the exporter and importer, respectively; Z_{ij} includes bilateral factors determining bilateral exports such as distance, contiguity and common language; $KyotoR_{jt}$ × carbon intensity_{ijkt} is the interaction term between a dummy variable for Kyoto ratifying importer and carbon intensity of sector k in the exporter country i and time t; $KyotoR_{jt}$ captures

[6] The words "commodity" and "sector" are used interchangeably throughout the paper.

[7] In their study, Mulatu and Wossink (2014) estimate the impact of environmental regulations on the choice of production location of the pig industry in Europe.

[8] Annex B countries include Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia , Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein , Lithuania, Luxembourg, Malta, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, United States of America.

the status of Kyoto ratification by the importer j at time t; K_{it} and K_{jt} are the regulatory quality indices[9] for exporter and importer respectively at time t; Fac_{ijt} is the ratio of the capital to labor ratios between the trading partners *i* and *j* at time t, which measures the similarity in factor endowment between the trading partners; we include year dummies to capture the effect of time varying variables; MR_{it} and MR_{jt} are the multilateral resistances[10] faced by i and j proxied by importer and exporter effects; the model captures the annual variation in exports by adding the year dummies[11]; v_{ij} represents bilateral pair dummies to control for trade pair heterogeneity. ε_{ijt} is a random disturbance assumed to be normal, and identically distributed with E $(\varepsilon_{ijt})=0$; Var $(\varepsilon_{ijt}) = \sigma^2 > 0$.

It should be noted that the aggregate trade costs of a country vary across different sectors. To capture this impact, we interact sector/commodity dummies with the multilateral resistance (MR) terms for exporter and importer (captured by exporter and importer fixed effects) in order to take into account varying elasticities of substitution across sectors. All Kyoto-ratifying countries have not ratified the protocol simultaneously though most of the countries have ratified it during the period between 2002 and 2005. Therefore, the information on Kyoto Protocol ratification by the trading partners has to be addressed in a way that captures the time of ratification of the Kyoto Protocol in the importer country. The impact of Kyoto Protocol policy on the exports from the South Asian economies is assessed by defining a dummy variable that takes into account the year of ratification of the Kyoto Protocol in the importer countries:

$KyotoR_{jt}$ = 1, if importer j has a binding emission cap and $t \geq$ year of ratification;

= 0, otherwise

As the aim is to evaluate the commodity-specific effect of the Kyoto Protocol, we define an interaction term of commodity-specific carbon intensity and carbon regulation proxied by the ratification of the Kyoto Protocol to determine the location of the exports, i.e., whether Kyoto ratification by trading partners attracts carbon-intensive goods or not.

The ratification of the Kyoto Protocol decision by Annex B countries may be endogenous for their imports but it is exogenous for the exports of South Asian countries. There could be differences in endowments, climatic conditions or carbon-related preferences in a country pair that impact the importer's decision to ratify the Kyoto protocol. This unobserved heterogeneity can be controlled by including country pair dummies in the estimation of the gravity model (Aichele and Felbermayr, 2015).

Anderson and Wincoop (2003) have suggested the incorporation of MR measures to deal with the problems arising from missing information on trade costs. According to Head and Mayer, in the absence of MR measures, the '*OLS is a poor estimator under the structural gravity DGP*' (2014, p. 155). They have observed, via a simulation study, that inclusion of the exporter and importer dummies in the gravity model and estimating it using OLS can solve the problem of missing information on trade costs as long as there are no other econometric problems.

Although most of the econometric studies on carbon leakage use the OLS method to estimate the gravity model of trade flows, the log linearization of the empirical gravity model in the presence of heteroscedasticity and zero trade flows leads to biased inconsistent estimates (Santos Silva and Tenreyro, 2006). The potential for heteroscedasticity exists even after attempts to include the multilateral resistance measures, mostly by incorporating fixed effects. Santos Silva and Tenreyro (2006) therefore suggest using the Poisson Pseudo Maximum Likelihood (PPML) estimator to simultaneously control for heteroscedasticity and for information contained in the zero values of trade flows.

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[9] This reflects the ability of a government to formulate and implement sound policies and regulations that permit and promote private sector development.

[10] Multilateral resistances represent average trade resistance between a country and its trading partners in an ideal aggregation

[11] Time dummies are used only for the combined case where all three South Asian economies are considered. In the case of individual country gravity models, the time dummies are excluded. Since the GDP in a single country case varies only across time, the coefficient of GDP when the time dummy is included cannot be identified and estimated. We are thankful to the anonymous reviewer for pointing this issue out.

Moreover, Fally (2015) shows that the use of PPML leads to a perfect fit between the fixed effects and their structural gravity counterparts. In other words, market clearing and budget allocation conditions of structural gravity models are satisfied when the PPML estimator is used, a condition proposed by Anderson and Yotov (2010, 2012) with respect to the validity of structural gravity models. However, recent literature suggests the use of statistical tests for choosing an appropriate model since the PPML estimator is not different from other estimators as far as bias and consistency of parameter estimates are concerned (Martinez-Zarzoso, 2013; Head and Mayer, 2014).

Taking the above issues into consideration, we therefore use both OLS and PPML estimation of the gravity model and base the choice of the model on RESET test statistics. We estimate equation (1) for commodity-specific exports, individually and combined, for three South Asian economies, namely, India, Pakistan and Sri Lanka.

3. Data

The analysis focuses on the export of selected commodities from India, Pakistan and Sri Lanka. The importers include top trading partners of the three economies – constituting 1 percent or more of their total exports of the mentioned categories of goods. We use the time- period between 2000 and 2012 for the analysis though, for Pakistan, the time-period is 2003 to 2012 due to constraints on data availability. Tables A1 and A2 in the Appendix list the commodities and the Kyoto and non-Kyoto trading partners of the three countries, respectively.

Selection of Commodities

We need information on the carbon intensities of commodities in order to assess the differential between the carbon content being exported to Kyoto-ratifying countries versus non-ratifying countries. However, the selection of commodities is constrained by the non-availability of data on commodity-specific carbon intensities. Bilateral export data for these selected commodities is retrieved from World Integrated Trade Solution (WITS), World Bank.

Carbon Intensity

We obtain sector-specific carbon intensities from Battacharjya and Nanda (2012). They focus on 30 key sectors selected from 130 sectors of India's Input Output Table for the year 2006-2007. Battacharjya and Nanda obtain the data for the sector-specific fuel consumption and emission intensity from the Annual Survey of Industries in India (ASI) and Parikh *et al.* (2009), respectively. We have grouped the sectors based on the nature of commodities where CO_2 emission intensity is defined as sector-specific emissions per unit of sectoral output. For computing sector-specific emissions, we multiply sector-specific fuel consumption with the emission intensity of the fuels, taking into consideration four types of fuels: coal, petroleum products, natural gas and electricity. We compute emission intensity by dividing the sectoral total emissions by the sectoral output.

Battacharjya and Nanda provide carbon intensities in terms of Kilo Tonnes/Million Indian rupees (INR). For standardization, we convert the sector-specific coefficients into Kilo Tonnes/USD by applying the annual India-US exchange rate. For Pakistan and Sri Lanka, we first convert Kilo Tonnes/INR Million to Kilo Tonnes per million Pakistani and Sri Lankan Rupees, respectively, using the annual India-Pakistan and India-Sri Lanka exchange rate, further converting it to Kilo Tonnes/USD through Pakistan-US and Sri Lanka-US annual exchange rates. This enables us to obtain sector-specific yearly carbon coefficients for all the three South Asian economies. For the purpose of the regression analysis, we rescale carbon intensities to Thousand Kilo Tonnes/USD.

Climate Policy

This paper attempts to assess the impact of climate policies adopted by the importers on the exports of the above-mentioned commodities from the three South Asian economies, the climate policy under consideration being the Kyoto protocol. We obtain Kyoto status (ratification and enforcement) of the importer countries from the UNFCCC homepage.

Other Covariates

We obtain GDP (in current USD) from the World Development Indicators (WDI) database. We take bilateral distance measures from the CEPII distances database. The country-level data for capital and labor is obtained from Penn World Tables, version 8. The Regulatory Quality indices are obtained from the World Bank's World Governance Indicators (WGI). The indicators lie in the range of -2.5 to 2.5[12].

Table 1 presents the descriptive statistics of the main variables used in the analysis. At the mean level, sectoral exports are higher for non-Kyoto binding countries relative to Kyoto- binding countries while the standard deviation 'between' is much higher than 'within' for both groups of countries. This table also reveals that the regulatory quality, at the mean level, is higher in the case of the trading partners than in the case of the South Asian countries.

4. Results and Discussion

Tables 2 to 5 provide the estimates of equation (1) for the commodity-specific exports of India, Pakistan and Sri Lanka, both individually and combined.[13] For each of the cases, we estimate four versions of equation (1). While RESET χ^2 values favor PPML estimator (model 3) for India and the combined case and PPML model 4 works for Pakistan, in the case of Sri Lanka, OLS (model 2) scores over PPML. It should also be noted that the PPML method does not report certain variables like exporter regulatory quality and contiguity in some cases as it uses the method of Santos Silva and Tenreyro (2010) to identify and drop regressors that may lead to the non-existence of the (pseudo-) maximum likelihood estimates.

The selected models reveal several interesting findings of significance. Firstly, the estimates on most of the standard gravity variables are as expected. The export elasticity of GDP shows that the volume of exports is positively and significantly associated with market size in all cases except India. In the case of India, India's GDP and its trading partners' GDP levels are not significant in explaining the sectoral exports.[14] Furthermore, distance significantly and negatively impacts the export levels of all three individual country cases (in all the individual country regressions, the coefficient of the variable distance is negative and statistically significant), thus proving to be a trade cost as suggested by the gravity theory. However, in the combined case, the coefficient of distance is negative and statistically insignificant lending support to the argument that globalization results in increased economic activity, thereby leading to a decrease in transport costs, which Brun *et al.* (2002) have called the '*death of distance*'. Contiguity and common language are insignificant in explaining the export levels in all cases except Pakistan where both bilateral variables result in a decline in its export level.

Secondly, we find that the parameter estimate of the relative factor ratio is negative for all cases except for Pakistan and that it is statistically significant only in the case of Sri Lanka. The negative sign of the relative factor ratio supports the Linder Hypothesis.

Our main interest lies in the coefficients of the Kyoto ratification term and the interaction term between the climate policy variable and sectoral carbon intensity. Since the climate policy variable is a dummy variable, the coefficient of the interaction term shows that exports from a South Asian country to a Kyoto-binding country as opposed to a non-Kyoto binding country is affected by the coefficient of the interaction term moderated by the carbon intensity of the commodity in question. For both the estimation techniques, OLS and PPML, the interaction variable carries a negative sign and is statistically significant and consistent for both the combined case as for individual country cases, except for Pakistan. For the linear Kyoto ratification term, the sign of the coefficient is negative and significant for Pakistan whereas it is significantly positive for Sri Lanka. However, for India as well as for the

[12] A statistical methodology known as Unobserved Components Model is used for the index generation in order to (i) standardize the data from these very diverse sources into comparable units, (ii) construct an aggregate indicator of governance as a weighted average of the underlying source variables, and (iii) construct margins of error that reflect the unavoidable imprecision in measuring governance.

[13] Detailed results can be obtained from the authors upon request.

[14] As Baldwin and Taglioni (2011) have pointed out, the GDP levels of origin and destination countries are inappropriate for bilateral flows of intermediate exports. Most of the commodities considered in the present study are intermediate products.

combined case, the Kyoto Protocol variable is insignificant. The net impact of Kyoto ratification on the exports of South Asian countries depends on three factors: the coefficients of the Kyoto ratification dummy and the interaction variable; the carbon intensity, i.e., α_5 and α_4 and carbon intensity (equation 2). We compute this impact for each of the individual countries as well as for the combined case. Table 6 presents the computed figures of the net impact.[15]

$$\frac{d\, in\, (x_{ijkt})}{d(kyotoR_{jt})} = \alpha_5 + \alpha_4 (\text{carbon intensity}_{ikt}) \qquad (2)$$

At the mean carbon intensity level, we observe that the net impact is negative and statistically significant for India and the combined case. For Sri Lanka, the net impact is not statistically significant whereas for Pakistan, the null hypothesis of carbon leakage could not be rejected. It is noteworthy that for India, the growth rate of carbon-intensive exports to the Kyoto ratifying countries vis-a-vis non-ratifying countries falls by a factor of 0.535 implying a negative leakage from India. For the combined scenario, too, there exists a negative leakage from the three South Asian countries by a factor of 0.37. In the case of Pakistan, the extent of positive leakage is by a factor less than unity, i.e., 0.55 at the average level of carbon intensity (see Table 6). However, the effect of the climate policy on exports is commodity-specific due to varying carbon intensities across sectors. For India and the combined case, we find that the carbon leakage effect is negative for all the commodities considered in the present study though the extent of negative leakage varies across sectors. The fall in the growth rate of carbon intensive exports to Kyoto-ratifying importers vis-a-vis non-ratifying ones or the extent of negative leakage is the maximum for the cement sector where the growth rate of exports drops by a factor of 4.975 and 4.57, respectively, for India and the combined case, whereas it is minimum for the agriculture sector with a fall in growth rate of exports by a factor of 0.034 and 0.031, respectively, for India and the combined scenario (see Table 6).

In the case of India, the rejection of the carbon leakage hypothesis is consistent with the findings of previous studies as well as empirical evidence. Dietzenbacher and Mukhopadhyay (2007), for instance, observe the presence of the 'green paradox' in the general equilibrium framework used in their study and find no evidence of the Pollution Haven Hypothesis in India's commodity trade with the rest of the world. India's comparative advantage in medium and high technology content industries has, for instance, improved since the late 1990s (Alessandrini *et al.* 2011); the same trend is observed for clean energy generating high-tech equipment (Sawhney and Kahn, 2012). Moreover, in a recent paper, Sawhney and Rastogi (2015) have reported that the value of India's trade in the dirty manufacturing sector with the group of Kyoto-ratifying high income countries, including the USA,[16] remained negative in the Michaely Index.[17] India's growing trade in the commodities considered here with non-Kyoto ratifying and low-income countries is expected to be driven by the resource endowment effect.

Similarly, in the case of Sri Lanka, we observe negative and significant carbon leakage for glass and glass products, iron and steel, fertilizer, and paper and paper products by a factor of 1.157, 0.806, 1.460, and 0.499, respectively, and positive carbon leakage for agricultural and related products, leather, electrical machinery, transport and its equipment, wood and wood products, pesticides, sugar and refined petroleum. The agriculture sector displays the maximum leakage; indeed, the growth rate of these exports to Kyoto-binding importers, in comparison with non-binding importers, rises by a factor of 0.591. With regard to carbon intensities of commodities, it can be observed that negative leakage exists for sectors with high carbon intensities and vice-versa, which results in an overall negative leakage effect. In the case of Pakistan, negative carbon leakage has been observed for agricultural and related services, chemicals, leather, electrical machinery, transport and related equipment, wood and wood products, coal and lignite, pesticides, sugar, refined petroleum and rubber. All the sectors which show a tendency for negative leakage are relatively less carbon intensive sectors, thereby displaying low factors through which the growth rate of exports to Kyoto-binding partners (vis-a-vis non-binding trading partners) falls, ranging between

[15] In the computation of the leakage effect, we involve only the coefficients of the variables that are statistically significant.

[16] Most Kyoto-ratifying countries are high income.

[17] The Michaely Index is a measure of specialization in trade at the disaggregated sector level which takes into account both exports and imports (Laursen, 1998)

0.203 and 0.857. However, positive carbon leakage has been found for the following commodities: glass and glass products, iron and steel, cement, fertilizer, paper and paper products, and textiles, which are relatively high carbon-intensive commodities, as reflected in the factor by which the growth rate of Pakistani exports of these commodities to Kyoto-binding importers rises as compared to non-binding ones, the maximum factor being 20.554 for the cement sector. With this trend, at the average level, a phenomenon of positive carbon leakage from Pakistan has been observed (see Table 6).

The regression results are also consistent with the observed trend in the carbon intensity of GDP in the South Asian countries and their trading partners. Figure 1 shows that though there is a declining trend in carbon intensity across all countries, the rate of decline is much faster in the South Asian countries in comparison with their Kyoto- and non-Kyoto-binding countries. Moreover, these trends in carbon intensities reflect that, during the time-period under consideration, the gap in the carbon intensity between South Asian countries and their trading partners has been declining, contrary to the assumptions of the Carbon Leakage Hypothesis.

5. Conclusions and Policy Implications

This study attempted to analyze the impact of unilateral climate policies in industrialized countries on the export of selected commodities from the South Asian countries. Kyoto- type climate policies are supposed to result in carbon leakage since these policies make carbon costly in the ratifying countries so that carbon intensive production shifts to countries that have no price for carbon, as a result of which carbon emission increases in such non-Kyoto-binding countries.

In order to analyze the Carbon Leakage Hypothesis, we took as our sample three South Asian countries, namely, India, Pakistan and Sri Lanka, none of which is Kyoto-binding. We found from the trade data that though exports of selected commodities from these countries were increasing, to arrive at the inference that it is a case of carbon leakage would be misleading. We therefore used the standard gravity model to test the Carbon Leakage Hypothesis. We estimated the gravity model using the PPML and OLS estimators, the choice of the model based on the statistical RESET test, which indicates the absence of the problem of heteroscedasticity.

The regression results obtained from the gravity model based on commodity-specific panel data of exports revealed the presence of negative carbon leakage in the case of India and Sri Lanka as well as for combined exports from the three countries to the Kyoto-binding countries. This finding of negative carbon leakage in the case of India is compatible with the finding of Sawhney and Rastogi (2015). However, in the case of Pakistan, the hypothesis of positive carbon leakage could not be rejected. However, the effect, whether negative or positive, was commodity-specific as well as modest in magnitude.

The Carbon Leakage Hypothesis is based on the assumption that unilateral climate policy will result in a significant increase in carbon prices in Kyoto-committed countries. The experience of carbon markets shows that the levels of existing carbon prices have been low which makes it difficult to disentangle the effect of small carbon prices from more trade-dominating factors such as exchange rates, transport costs, trade agreements, and relative costs of labor, capital and other inputs (Demailly and Quirion, 2008). Even if production costs were to increase due to the introduction of unilateral climate policy, as Sato and Dechezleprêtre (2015) have pointed out, the producers may be able to pass on the increase in production costs to their consumers because of high transport costs or product differentiation associated with imports such that their trade and investment decisions would remain unaffected by positive carbon prices.

The evidence of negative carbon leakage from the South Asian countries, particularly from India and Sri Lanka, suggests that the concerns regarding carbon leakage should not be the determinants of climate and trade policies. The explanations for negative carbon leakage might be the result of 'environmentally benign technological transfers' and/or the 'abatement resource effect', which could be the subject matter of future research in this area.

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Tables

Table 1: Descriptive Statistics for South Asia

	Total				Kyoto-binding countries				Non-Kyoto-binding countries			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Exports (USD Billion)	0.42	11.21	0	557.24	0.05	0.17	0	5.09	0.64	14.26	0.00	557.24
GDP Exporter (USD Billion)	533.13	575.50	16.33	1880.10	527.58	593.37	17.10	1880.10	536.56	564.15	16.33	1880.10
GDP Importer (USD Billion)	1697.21	2879.63	5.27	15500.00	1880.65	1205.92	252.80	5905.63	1583.36	3535.95	5.27	15500.00
Distance (Kilometers)	6016.71	3333.46	683.37	17101.06	7340.06	2046.40	3658.64	14029.91	5195.45	3694.43	683.37	17101.06
Contiguity	0.10	0.30	0	1	0	0.00	0	0	0.16	0.37	0	1
Common Language	0.19	0.39	0	1	0.15	0.36	0	1	0.21	0.41	0	1
Kyoto Ratification	0.38	0.49	0	1	1	0.00	1	1	0	0	0	0
Carbon Intensity (Thousand Kilo Tonnes/ USD Million)	0.36	0.76	0.03	5.356	0.338	0.69	0.03	5.35	0.38	0.8	0.03	5.35
Kyoto Ratification* Carbon Intensity(Thousand Kilo Tonnes/USD Million)	0.13	0.46	0	5.356	0.338	0.69	0.03	5.35	0	0	0	0
Factor Ratio	0.40	0.56	0.03	3.31	0.10	0.05	0.04	0.36	0.59	0.64	0.03	3.31
Exporter Regulatory Quality	-0.32	0.22	-0.88	0.25	-0.34	0.21	-0.88	0.18	-0.32	0.23	-0.88	0.25
Importer Regulatory Quality	0.64	0.92	-1.73	2.12	1.32	0.46	-0.41	1.86	0.22	0.87	-1.73	2.12

Notes: Bilateral exports are extracted from the WITS database, World Bank. GDP (in current USD) is obtained from the World Development Indicators (WDI) database. Bilateral distance measures (Distance, Common Language, Contiguity) are taken from the CEPII distances database. The country level data for capital and labor is obtained from Penn World Tables, version 8. The Regulatory Quality indices are obtained from the World Bank"s World Governance Indicators (WGI). The indicators lie in the range between -2.5 and 2.5. The sector-specific carbon intensities are taken from Battacharjya and Nanda (2012) and the information for the Kyoto ratification is obtained from the UNFCCC homepage.

Table 2: Regression results for gravity model estimation for India

	OLS(1)	OLS(2)	PPML(3)	PPML(4)
	Log (Exports)	**Log (Exports)**	**Exports**	**Exports**
Log (GDP exporter)	0.682***	0.840***	0.990	1.561***
	(3.02)	(11.23)	(0.42)	(4.78)
Log (GDP importer)	0.758***	0.669***	2.701	1.266***
	(2.65)	(10.04)	(0.85)	(3.50)
$Kyoto_{jt}$ × carbon $intensity_{ikt}$	-1.48***	-0.729***	-1.03***	0.0579
	(-21.43)	(-8.31)	(-6.02)	(0.25)
Kyoto Ratification	0.772***	0.264**	-1.080	-1.459***
	(3.19)	(2.35)	(-0.78)	(-5.68)
Exporter Regulatory Quality	-1.159*	-1.272***	-2.041	-2.076*
	(-1.84)	(-4.26)	(-0.39)	(-1.88)
Importer Regulatory Quality	-0.0289	-0.131	0.801	1.348**
	(-0.08)	(-1.07)	(0.24)	(2.54)
Factor Ratio	0.200	0.463**	-5.560	-4.499***
	(0.31)	(1.97)	(-1.39)	(-5.75)
Constant	-15.98***	0.00105	3.549	-1.022
	(-5.56)	(0.00)	(0.13)	(-0.19)
Number of Observations	4541	4541	4541	4541
RESET F/chi Square	10.71	16.55	1.92	387.34
RESET p-Values	0.0011	0.000	0.1653	0.000
Bilateral Variables	Yes	Yes	Yes	Yes
Importer Fixed Effects	Yes		Yes	
Time Effects	No	No	No	No
Commodity × Importer Effects		Yes		Yes

Notes: * p≤0.1, ** p0.05, *** p≤0.01; values in parentheses are 't' statistics.

The RESET test is based on the methodology explained by Santos Silvaand Tenreyro (2006), p. 646.

Table 3: Regression results for gravity model estimation for Pakistan

	OLS(1)	OLS(2)	PPML(3)	PPML(4)
	Log (Exports)	**Log (Exports)**	**Exports**	**Exports**
Log (GDP exporter)	-0.611 (-1.20)	-0.184 (-1.22)	-0.0341 (-0.05)	0.296** (2.35)
Log (GDP importer)	0.636 (1.15)	0.459*** (4.34)	0.649 (0.93)	0.493*** (3.72)
$Kyoto_{jt}$ × carbon $intensity_{ikt}$	-2.69*** (-5.24)	2.58** (2.19)	0.528*** (3.09)	4.46*** (5.47)
Kyoto Ratification	0.856 (1.29)	-0.563** (-2.14)	0.0902 (0.16)	-1.006*** (-4.36)
Exporter Regulatory Quality	-0.0588 (-0.08)	0.163 (0.53)	0.0709 (0.06)	-0.110 (-0.45)
Importer Regulatory Quality	-1.042 (-1.33)	-0.706*** (-3.69)	0.255 (0.20)	-0.109 (-0.68)
Factor Ratio	-0.852 (-0.83)	0.149 (0.56)	-1.062 (-0.97)	0.313 (1.26)
Constant	-0.668 (-0.08)	10.15*** (3.24)	34.56 (1.47)	5.422** (2.16)
Number of Observations	2268	2268	2315	2315
RESET F/chi Square	18.38	1.22	0.22	1.06
RESET p-Values	0.000	0.2686	0.6395	0.3028
Bilateral Variables	Yes	Yes	Yes	Yes
Importer Fixed Effects	Yes		Yes	
Time Effects	No	No	No	No
Commodity × Importer Effects		Yes		Yes

Notes: * p≤0.1, ** p0.05, *** p≤0.01; values in parentheses are 't' statistics.

The RESET test is based on the methodology explained by Santos Silvaand Tenreyro (2006), p. 646.

Table 4: Regression results for gravity model estimation for Sri Lanka

	OLS(1)	OLS(2)	PPML(3)	PPML(4)
	Log (Exports)	Log (Exports)	Exports	Exports
Log (GDP exporter)	0.254 (0.84)	0.0453 (0.35)	0.321 (1.27)	0.340*** (4.46)
Log (GDP importer)	0.829** (2.46)	0.957*** (10.91)	0.649** (2.01)	0.313*** (6.25)
$Kyoto_{jt}$ × carbon $intensity_{ikt}$	-6.84*** (-15.60)	-2.39*** (-4.23)	-2.13*** (-5.80)	-3.21*** (-6.12)
Kyoto Ratification	1.389*** (4.43)	0.670*** (3.73)	0.303 (1.25)	0.678*** (5.95)
Exporter Regulatory Quality	-0.418 (-0.91)	-0.696*** (-2.86)	0.184 (0.45)	-0.00615 (-0.03)
Importer Regulatory Quality	-0.410 (-0.68)	-2.274*** (-16.42)	0.0748 (0.14)	-0.977*** (-16.48)
Factor Ratio	-0.963** (-1.98)	-0.648*** (-3.74)	-0.0319 (-0.08)	-0.203** (-2.15)
Constant	23.93 (1.45)	-6.679** (-2.28)	-3.994 (-0.29)	-4.403*** (-2.74)
Number of Observations	2910	2910	2921	2921
RESET F/chi Square	0.75	0.03	6.18	12.87
RESET p-Values	0.3867	0.8665	0.0130	0.0003
Bilateral Variables	Yes	Yes	Yes	Yes
Importer Fixed Effects	Yes		Yes	
Time Effects	No	No	No	No
Commodity × Importer Effects		Yes		Yes

Notes: * p≤0.1, ** p0.05, *** p≤0.01; values in parentheses are ‘t’ statistics.

The RESET test is based on the methodology explained by Santos Silvaand Tenreyro (2006), p. 646.

Table 5: Regression results for gravity model estimation for South Asia

	OLS(1)	OLS(2)	PPML(3)	PPML(4)
	Log (Exports)	**Log (Exports)**	**Exports**	**Exports**
Log (GDP exporter)	2.572*** (3.97)	1.915*** (5.77)	1.450 (0.61)	1.107* (2.27)
Log (GDP importer)	0.803*** (3.96)	0.894*** (8.64)	0.999** (1.96)	1.009*** (6.89)
$Kyoto_{jt}$ × carbon $intensity_{ikt}$	-1.69*** (-22.42)	-0.154 (-1.37)	-0.950*** (-6.61)	-1.22* (-2.43)
Kyoto Ratification	0.399** (2.01)	-0.239* (-2.22)	-0.578 (-0.89)	-0.574** (-2.70)
Factor Ratio	-0.320 (-0.98)	-0.156 (-0.94)	-1.841 (-0.88)	-1.988*** (-5.59)
Exporter Regulatory Quality	-0.426 (-1.41)	-0.373* (-2.42)	-0.140 (-0.13)	-0.0817 (-0.27)
Importer Regulatory Quality	-0.288 (-0.96)	-0.127 (-0.83)	0.709 (0.48)	0.696* (2.44)
Constant	-17.52 (-1.26)	-52.33*** (-7.96)	26.58 (0.46)	-8.927 (-0.76)
Number of Observations	9719	9719	9777	9777
RESET F/chi Square	11.67	52.08	2.67	12.79
RESET p-Values	0.0006	0.0000	0.1083	0.0003
Bilateral Variables	Yes	Yes	Yes	Yes
Importer Fixed Effects	Yes		Yes	
Exporter Effects	Yes		Yes	
Time Effects	Yes	Yes	Yes	Yes
Commodity × Importer Effects		Yes		Yes
Commodity × Exporter Effects		Yes		Yes
Commodity Pair Effects	Yes	Yes	Yes	Yes

Notes: * p≤0.1, ** p0.05, *** p≤0.01; values in parentheses are ‘t’ statistics.

The RESET test is based on the methodology explained by Santos Silvaand Tenreyro (2006), p. 646.

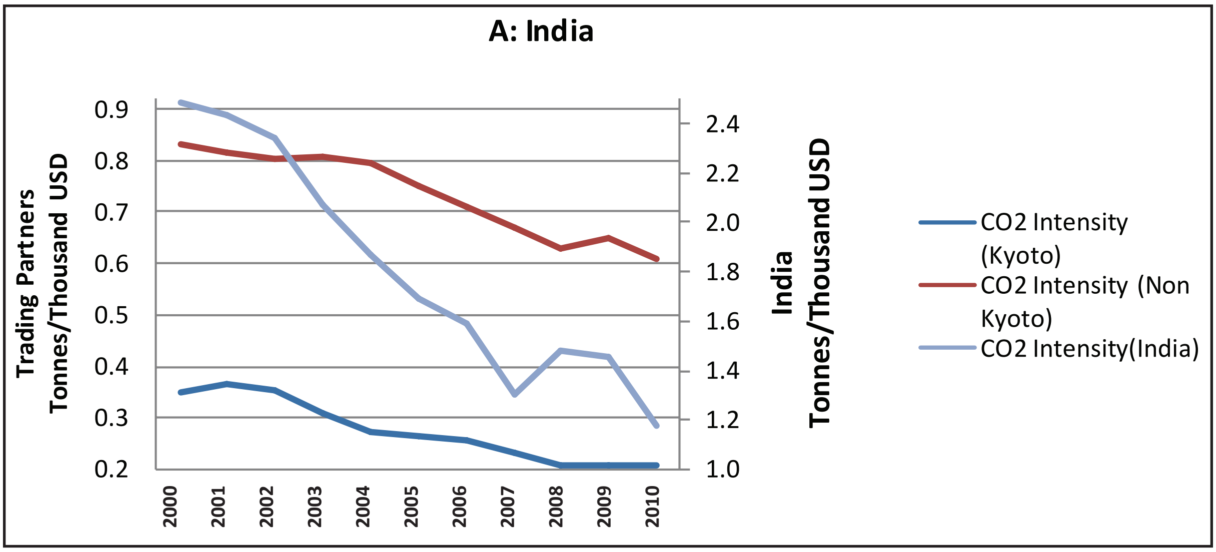
Table 6: Net impact of Kyoto ratification on the exports

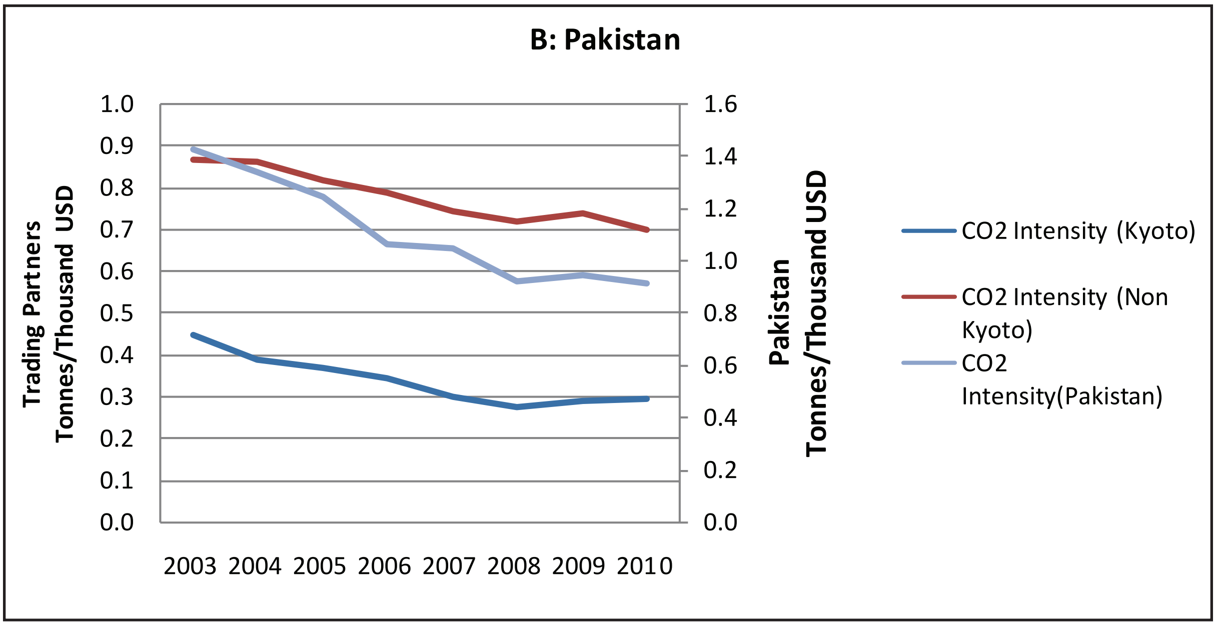
Sector	ISIC (Revision 3) code	India (Model 3)	Pakistan (Model 4)	Sri Lanka (Model 2)	Combined (Model 3)
Agriculture and Related Services	01	-0.034*** (-6.020)	-0.857*** (-4.140)	0.591*** (3.480)	-0.031*** (-6.610)
Manufacture of Basic Chemicals	2411	-0.185*** (-6.020)	-0.203* (-1.640)	0.241 (1.630)	-0.170*** (-6.610)
Manufacture of Glass and Glass Products	261	-0.790*** (-6.020)	2.422*** (5.520)	-1.157*** (-3.190)	-0.726*** (-6.610)
Manufacture of Basic Iron and Steel	271	-0.638*** (-6.020)	1.759*** (5.450)	-0.806*** (-2.790)	-0.586*** (-6.610)
Tanning and Dressing of Leather	191	-0.096*** (-6.020)	-0.591*** (-3.520)	0.448*** (2.870)	-0.088*** (-6.610)
Manufacture of Electrical Machinery	31	-0.053*** (-6.020)	-0.764 (-3.960)	0.547*** (3.310)	-0.049*** (-6.610)
Manufacture of Transport and Transport Equipments	35	-0.085*** (-6.020)	-0.637*** (-3.650)	0.473*** (2.990)	-0.078*** (-6.610)
Manufacture of Wood and Wood Products	20	-0.068*** (-6.020)	-0.711*** (-3.840)	0.512*** (3.170)	-0.063*** (-6.610)
Mining of Coal and Lignite	10	-0.047*** (-6.020)	-0.803*** (-4.040)		-0.043*** (-6.610)
Manufacture of Cement	2694	-4.975*** (-6.020)	20.554*** (5.490)		-4.570*** (-6.610)
Manufacture of Fertilizers and Nitrogen Compounds	2412	-0.921*** (-6.020)	2.988*** (5.540)	-1.460*** (-3.400)	-0.846*** (-6.610)
Manufacture of Pesticides and Other Agro Chemical Products	2421	-0.162*** (-6.020)	-0.303** (-2.280)	0.295** (1.980)	-0.149*** (-6.610)
Manufacture of Sugar	1542	-0.125*** (-6.020)	-0.463*** (-3.060)	0.380** (2.500)	-0.115*** (-6.610)
Manufacture of Paper and Paper Products	210	-0.506*** (-6.020)	1.185*** (5.220)	-0.499** (-2.180)	-0.465*** (-6.610)
Manufacture of Refined Petroleum	232	-0.111*** (-6.020)	-0.526*** (-3.300)	0.414*** (2.690)	-0.102*** (-6.610)
Manufacture of Plastic and Plastic Products	252	-0.192*** (-6.020)	-0.176 (-1.440)	0.227 (1.530)	-0.176*** (-6.610)
Manufacture of Rubber and Rubber Products	251	-0.146*** (-6.020)	-0.374*** (-2.660)	0.333** (2.220)	-0.134*** (-6.610)
Manufacture of Textiles	17	-0.282*** (-6.020)	0.217* (1.930)	0.018 (0.110)	-0.259*** (-6.610)
Average		-0.535*** (-6.020)	0.550*** (4.000)	0.094 (0.620)	-0.370*** (6.61)

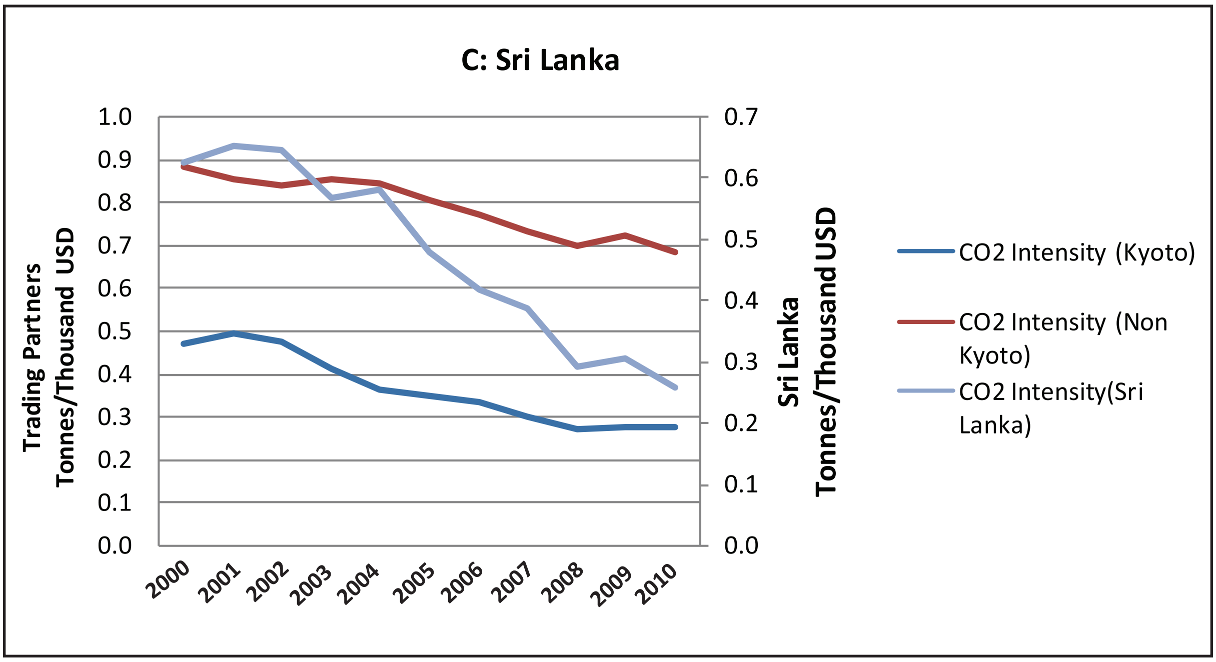
* p≤0.1, ** p≤0.05, *** p≤0.01; values in parentheses are 't' statistics.

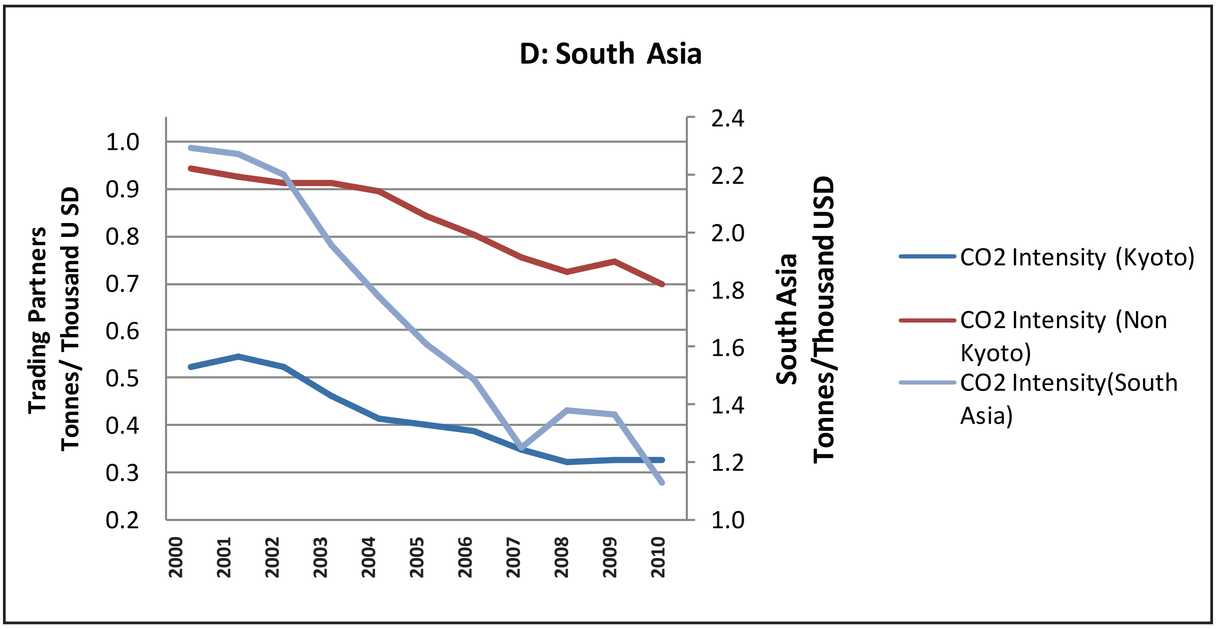
Figures

Figure 1: CO_2 Intensity in South Asian countries and their trading partners









Source: Based on World Development Indicators, World Bank

Appendix

Table A1: List of commodities

Sector	ISIC (Revision 3) Code
Agriculture and Related Services	01
Manufacture of Basic Chemicals	2411
Manufacture of Glass and Glass Products	261
Manufacture of Basic Iron and Steel	271
Tanning and Dressing of Leather	191
Manufacture of Electrical Machinery	31
Manufacture of Transport and Transport Equipments	35
Manufacture of Wood and Wood Products	20
Mining of Coal and Lignite	10
Manufacture of Cement	2694
Manufacture of Fertilizers and Nitrogen Compounds	2412
Manufacture of Pesticides and Other Agro Chemical Products	2421
Manufacture of Sugar	1542
Manufacture of Paper and Paper Products	210
Manufacture of Refined Petroleum	232
Manufacture of Plastic and Plastic Products	252
Manufacture of Rubber and Rubber Products	251
Manufacture of Textiles	17

Table A2: Trading partners of South Asian countries

India		Pakistan		Sri Lanka	
Kyoto	Non-Kyoto	Kyoto	Non-Kyoto	Kyoto	Non-Kyoto
Australia	Bangladesh	Belgium	Afghanistan	Australia	Azerbaijan
Belgium	Brazil	France	Bangladesh	Belgium	Bangladesh
France	China	Germany	China	France	China
Germany	Egypt, Arab Rep.	Italy	Egypt, Arab Rep.	Germany	Egypt, Arab Rep.
Italy	Indonesia	Netherlands	Hong Kong, China	Italy	India
Japan	Korea, Rep.	Russian Federation	India	Japan	Iran, Islamic Rep.
Netherlands	Malaysia	Spain	Indonesia	Netherlands	Malaysia
Spain	Nepal	Turkey	Korea, Rep.	Russian Federation	Mexico
United Kingdom	Pakistan	United Kingdom	Malaysia	Spain	Pakistan
	Saudi Arabia		Saudi Arabia	Turkey	Saudi Arabia
	Singapore		South Africa	United Kingdom	Syrian Arab Republic
	South Africa		Sri Lanka		United Arab Emirates
	Sri Lanka		United Arab Emirates		United States
	Thailand		United States		
	United Arab Emirates		Vietnam		
	United States				

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