Can trade agreements curtail trade creation and prevent trade diversion?

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Abstract

In spite of the recent theoretical literature on the cross effects between preferential trade agreements (PTAs) such as the "domino effect" and "competitive liberalization" theory, little has been done to investigate how these effects impact on bilateral trade flows. In this paper we study two *cross* PTA effects: how *pre-existing* PTAs will dilute (shield) the trade creation (diversion) effect of *new* PTAs. We develop a theoretical foundation of cross PTA effects and find strong empirical evidence of both the dilution and shielding effects from various models that control for biases due to unobserved omitted variables, sample selection and firm heterogeneity. It is found that, although the dilution effect is sizable, the net trade creation effect remain substantial and positive, while both the shielding and net trade diversion effects are small. As a result, the positive inter-bloc trade effect of PTAs dominates the negative extra-bloc trade effect. These findings do not support the recent theoretical studies which explain the recent surge of PTAs on the ground that they could be used as a defensive device against trade diversion.

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1 Introduction

The last two decades witnessed a surge in the number of preferential trade agreements (PTAs).[1] A World Trade Organization (WTO) member country would be, on average, a signatory of six PTAs (Saggi and Yildiz (2010)). This has ignited enormous interest in investigating the effects of PTAs on trade flows between members and between members and non-members.[2] However, most of previous empirical works, following Viner (1950)'s trade creation/diversion paradigm, focus singularly on the *individual* effects of PTAs and ignore their *cross* effects. This omission is surprising given the large theoretical literature on the latter issue.

A "concession erosion effect" noted by Bagwell and Staiger (2004), Goyal and Joshi (2006) and Chen and Joshi (2010) indicates that the gain for a country from a new PTA is reduced by pre-existing PTAs between its partner country and some third countries. A "domino theory" introduced by Baldwin (1993) shows that trade diversion increases the incentives for non-memember countries to join an existing PTA. Egger and Larch (2008), Bagwell and Staiger (1997) and Baier et al. (2011) argue that the current proliferation of regionalism can be due to "competitive liberalization" and "tariff complementarity effect" in which countries attempt to use one PTA to reduce (or prevent) trade diversion from the other PTAs.

As exceptions, Egger and Larch (2008), Chen and Joshi (2010), and Baier et al. (2011) empirically study the effects of the "competitive liberalization", "concession erosion" and "tariff complementarity" respectively. Notwithstanding, all these studies look at the propensity of PTA formation, and still ignore the cross effects between PTAs on *trade flows*. This paper aims to fill this gap by investigating how *pre-existing* PTAs may affect the impacts of *new* PTAs on both intra-bloc and extra-bloc trade flows.

The trade creation/diversion paradigm suggests that, when country i forms a PTA with country j, it will increase imports from j (the trade creation effect) but potentially reduce imports from other countries (the trade diversion effect), largely due to changes in the relative prices of imports from different sources. However, the trade creation effect of the *new* PTA on i's imports from j may be smaller if i has already engaged in PTAs with some other countries—we call this the "trade dilution effect". We show that trade dilution arises as j's firm cannot enjoy the cost advantage over k's firm in i's market if i and k have already formed a PTA. In parallel, an existing PTA between i and j may mitigate the trade diversion effect on i's imports from j from late coming PTAs signed by i with other countries—we call this the "(trade diversion) shielding effect". Trade shielding arises because j's firm is less affected by losing the cost advantage in i's market as i was importing larger quantity due to its pre-existing PTA with j compared to no PTA between i and j.

Accounting for the dilution and shielding effects is important, because otherwise the estimates of the PTA effect on trade flows will overstate the magnitude of trade creation and diversion for countries with one or more pre-existing PTAs. Furthermore, an affirmative evidence of the shielding effect may help explain why the formation of PTAs by some countries appear to prompt even more subsequent PTAs as pointed out by Egger and Larch (2008) and Baier et al.

[1]As of 15 January 2012, 511 regional trade agrements have been notified to the World Trade Organization (WTO), and 319 of them were in force.

[2]See Magee (2003, 2008), Baier and Bergstrand (2004, 2007, 2009), Chen and Joshi (2010), and **?** for the recent literature.

(2011).

Our empirical models are based on the most commonly used gravity equation framework. The recent literature, however, identifies several biases in the traditional estimates of the gravity equation. Following that, in our estimations we account for unobserved country-pair heterogeneity using country-pair fixed effects (CPFEs) Magee (2003); Baldwin and Taglioni (2006); Baier and Bergstrand (2007) and multilateral resistance terms by adding country-time fixed effects (CTFEs) Anderson and van Wincoop (2003); Subramanian and Wei (2007); Magee (2008); **?**. Our empirical estimates of log liner models show that a rise in intra-bloc trade with PTA decreases dramatically from 328% to 68 % with CPFEs, and further down to 34% with CTFEs in addition. These results highlight the importance of accounting for both country-pair and country-time unobserved heterogeneity in the gravity model.

When CTFEs are included, however, it is not possible to identify both the trade creation and diversion effects due to perfect multicollinearity; as such, previous studies tend to omit trade diversion when controlling for CTFEs (e.g. Magee (2008); **?**). We propose two new methods to address this problem. One is that we allow CTFEs to vary for every *two/three* year, not every year. The other is that we apply the correlated random effect (CRE) approach as in Chamberlain (1980) and Mundlak (1978).

Given the large number of zero observations in trade flow data, self-selection of trade and the extensive margin can be another source of bias (Helpman et al., 2008). Besides the log linear models, we use the two-stage Heckman (1979) procedure to control for self-selection and the Helpman et al. (2008) procedure to control for the extensive margin.

Lastly, Silva and Tenreyro (2006, 2011) argue that the OLS (Ordinary Least Square) estimator in log linearized models suffers from severe bias caused by heteroskedastic errors, and suggest to use Poisson Pseudo-Maximum likelihood (PPML) estimator instead. However, the PPML estimator does not control for CPFEs, which is crucial in avoiding bias in estimating the PTAs effects. For instance, in our estimations of the trade diversion effect, the OLS estimator overstates it by 180 percentage points and the PPML estimator by 120 percentage points. We address this problem by applying the Conditional Poisson Pseudo-Maximum likelihood (CPPML) estimator suggested by Westerlund and Wilhelmsson (2011), which can control for both CPFEs and CTFEs.

Once we control for both CPFEs and CTFEs, we reach the same qualitative conclusion for all the model specifications and estimation methods considered in this paper. First, the dilution effect is both statistically and economically significant. For instance, the formation of a PTA increases intra-bloc trade volume by 34% with the first PTA, but moderating to 18% after incorporating the dilution effect in the log-linear model. Second, the shielding effect is significant statistically, but not so economically due to the trade diversion effect itself being very small in absolute terms. Extra-bloc trade flows decrease by 0.7% with the first PTA and by 0.6% after incorporating the shielding effect in the log-linear model. Our findings therefore cast doubt on the idea of using a PTA as a defensive device to mitigate any adverse effects of other PTAs. In other words, in contemplating a PTA, the primary consideration should remain the gain from trade creation even at the presence of the dilution effect.

The rest of the paper is organized as follows. Section 2 illustrate the idea of the trade dilution and shielding effects. In section 3, we develop the theoretical foundation using a three-country model. Section 4 explains the empirical methodology. Section 5 describes data set to be used.

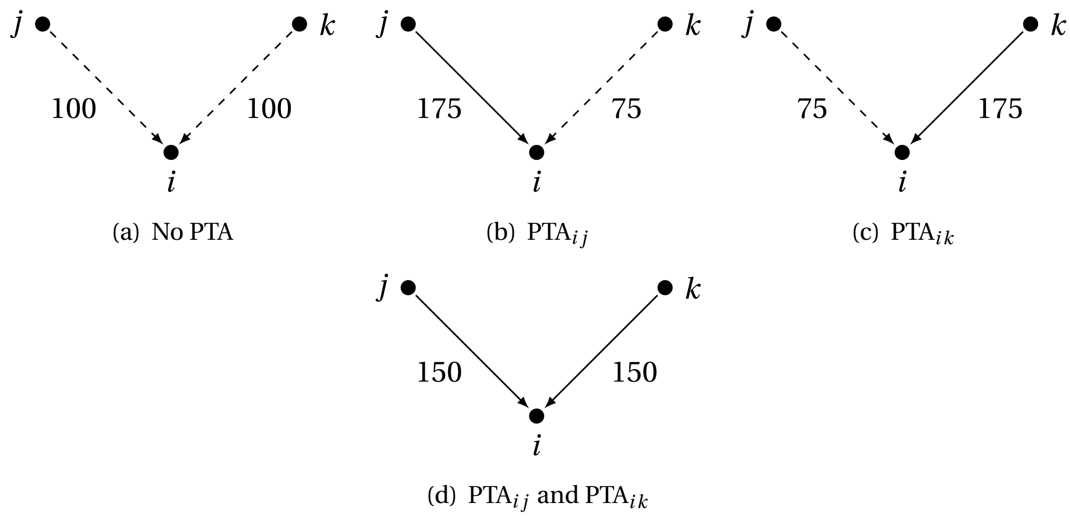


Figure 1: Dilution and shielding effects

Section 6 reports the results and the last section concludes.

2 The trade dilution and shielding effects

We illustrate the idea of the dilution and shielding effects in Figure 1. First, Panels (a), (b), and (d) show the trade dilution effect. Panels (a) and (b) indicate that $i's$ imports from j change from 100 units to 175 units, implying 75% change increase with a PTA. However, if i and k have already had a PTA in place before, as Panels (a) and (d) show, i's imports from j increase only 50% (from 100 units to 150 units). i's imports from j increase less by 25 percentage points due to the existing PTA between i and k. We call this the trade trade dilution. As shown in a theoretical model in Section 3, the trade dilution arises as j's firm cannot enjoy the cost advantage over k's firm in i's market if i and k have already formed a PTA. Next, Panels (a), (b), (c), and (d) show the trade shielding effect. Panels (a) and (c) indicate that $i's$ imports from j change from 100 units to 75 units, implying 25% change decrease with PTA between i and k. However, if i and j have already had a PTA in place before, as Panels (b) and (d) show, i's imports from j decrease only 14% (from 175 units to 150 units) with PTA between i and k. i's imports from j decrease less by 11 percentage points due to the existing PTA between i and j. We call this the trade shielding. The trade shielding arises because j's firm is less affected by losing the cost advantage in i's market as i was importing larger quantity due to its pre-existing PTA with j compared to no PTA between i and j.

3 The model

In this section,we construct a three-country model to examine how a country's imports from a PTA member country and the third country depend on the presence of existing PTA, and obtain the dilution and shielding effect in order to infer the sign of the trade creation and trade diversion effects of the following PTAs. First, we define the trade creation and trade diversion. Then, we examine how existing PTAs affect the trade creation and trade diversion.

3.1 Trade creation and trade diversion

Following Brander and Krugman (1983) and Krishna (1998), we consider three countries, labeled x, y, and z. The numeraire good and a homogeneous good, q, are produced with constant return to scales by each country i, $i = x, y, z$. There is one firm producing the homogeneous good in each country and competing in a Cournot fashion in the segmented markets. The firm in country i faces the marginal cost of c_i, which is independent of output level. Fixed costs, for simplicity, are ignored. The demand for the product by the consumers in country i is $P_i = A_i - Q_i$, where P_i is the market price and Q_i is the demand. Denote the supply of the product by a firm in country i to the market in j by q_i^j, i, $j = x, y, z$. In equilibrium, $Q_i = \Sigma_j q_i^j$. While transport costs are zero, country i imposes a specific tariff t_j^i on the good imported from country j, with $t_i^i = 0$.

The profit of the firm in country i, π_i, is the sum of the profits from all markets, i.e., $\pi_i = \Sigma_j \pi_i^j$, where π_i^j is the profit from market j:

$$\pi_i^j = q_i^j [A_j - Q_j - (c_i + t_i^j)] \tag{1}$$

where $t_i^j = 0$ if $i = j$ or $t_i^j = t$if $i \neq j$. The firm chooses the outputs, q_i^j, to maximize its profit, taking the tariff rate and the outputs of all other firms as given.

The Nash equilibrium supply by a firm in country i to country j is given by:

$$q_i^j = \frac{1}{4}(A_i - 3c_i + \Sigma_{k \neq i} c_k + \Sigma_k t_k^j) - t_i^j. \tag{2}$$

where $k = x, y, z$.

We further assume that initially, all countries impose the same non-discriminatory MFN tariff, $t_i^j = t_i > 0$ for $i \neq j$, and forming PTA between i and j implies $t_i^j = 0$.

Thus, for example, x's imports from y in the absence of any PTA of x is

$$q_y^x = \frac{A_x - 3c_y + c_x + c_z - 2t_x}{4}. \tag{3}$$

We assume the initial imports from i from j is positive: that is $A_x - 3c_y + c_x + c_z - 2t_x > 0$.

x's imports from y in the presence of PTA between x and y is

$$_{xy}q_y^x = \frac{A_x - 3c_y + c_x + c_z + t_x}{4}. \tag{4}$$

From (2) and (4), we can obtain the percentage change in x's imports from y with PTA between x and y, which is defined as trade creation effect in this paper:

$$_{xy}TC = \frac{_{xy}q_y^x - q_y^x}{q_y^x} = \frac{3t_x}{A_x - 3c_y + c_x + c_z - 2t_x} > 0, \tag{5}$$

where ${}_{xy}q_x^z$ refers to x' imports from y in the presence of PTA between x and y. The positive sign of ${}_{xy}TC$ means that x's imports from y increases with PTA between them.

Next, we calculate the trade diversion effect, which is defined as the percentage change in x's imports from z with PTA between x and y:

$$ {}_{xy}TD = \frac{{}_{xy}q_z^x - q_z^x}{q_y^x} = \frac{t_x}{A_x - 3c_y + c_x + c_z - 2t_x} < 0. \tag{6} $$

The positive sign of ${}_{xy}TC$ means that x's imports from z increases with PTA between x and y.

3.2 Trade dilution effect

Now we examine how a country's imports from a PTA member depend on the presence of existing PTA of the member country. We define the trade dilution effect of PTA as the difference of the percentage change in imports from the member country for for the PTA given PTA with other country and the PTA with no PTA with other country.

Thus, the trade dilution effect of PTA between x and y due to PTA between x and z can be written as

$$ TDL = \left(\frac{{}_{xy|xz}q_y^x - q_y^x}{q_y^x} \right) - \left(\frac{{}_{xy}q_y^x - q_y^x}{q_y^x} \right), \tag{7} $$

where "$xy|xz$" represents the situation in which PTA between x and y is formed in the presence of PTA between x and z.

From (2) ${}_{xy}q_y^x$ is

$$ {}_{xy|xz}q_y^x = \frac{A_x - 3c_y + c_x + c_z}{4}. \tag{8} $$

Plugging (3), (5), and (8) into (7) yields

$$ TDL = \frac{-t_x}{A_x - 3c_y + c_x + c_z - 2t_x} < 0. \tag{9} $$

The negative sign of the trade dilution indicates that x's imports from y increase less in the presence of PTA with the third country.

Intuitions are as follows: from (5), x increases its imports from y by $\frac{3t_x}{A_x - 3c_y + c_x + c_z - 2t_x}$ percentage point more as it forms the first PTA with y. These increases which arise due to an elimination of $t_x^y = t_x$ can be decomposed into three parts. The first $\frac{t_x}{A_x - 3c_y + c_x + c_z - 2t_x}$ percentage point comes from newly created market as prices in x decreases. Another $\frac{t_x}{A_x - 3c_y + c_x + c_z - 2t_x}$ percentage point is taken over from x's initial share to y due to the y's relative costs reduction compared to x's costs. These two components are *net* trade creation. The last $\frac{t_x}{A_x - 3c_y + c_x + c_z - 2t_x}$ percentage point is attributed to trade diverted from z due to y's relative costs reduction compared to z's costs.[3] The effect from the fist two factors remain in the presence of PTA between x

[3] All these changes can be easily shown by comparing the initial market share of each country in x and market share after PTA between x and y.

and z: ${}_{xy|xz}TC = \frac{{}_{xy|xz}q_y^x - q_y^x}{q_y^x} = \frac{2t_x}{A_x - 3c_y + c_x + c_z - 2t_x}$. However, if x and z have already formed PTA in an earlier stage, y's firm cannot enjoy the cost advantage over z's firm in i's market. Thus, once x has already formed an PTA with z, x's imports from y do not increase as much as those in the absence of PTA between x an z.

(9) gives us the following proposition.

Proposition 1. *A country's PTA with the third country reduces the increase of its imports from the PTA member country.*

3.3 Trade shielding effect

Now we examine how a country's imports from a non-member depend on the presence of existing PTA with that country. We define the shielding effect as the difference of the percentage change in imports from the non-member country for the PTA given PTA with non-member country and for the PTA without PTA with non-member country .

Thus, the trade shielding effect of PTA between x and z due to the existing PTA between x and z can be written as

$$TSD = \left(\frac{{}_{xy|xz}q_z^x - {}_{xz}q_z^x}{{}_{xz}q_z^x}\right) - \left(\frac{{}_{xy}q_z^x - q_z^x}{q_z^x}\right). \tag{10}$$

Both the term in the first parenthesis and the term in the second parenthesis are negative as x's imports from z decrease as x forms a PTA with y.

Given the condition of ${}_{xy|xz}q_z^x > 0$,we can easily obtain TSD from (2):

$$TSD = \frac{3t_x^2}{(A_x - 3c_y + c_x + c_z + t_x)(A_x - 3c_y + c_x + c_z - 2t_x)} > 0. \tag{11}$$

The positive sign of the trade dilution indicates that x's imports from z decreases less due to ${}_{xy}PTA$ if it has already formed PTA with z. Trade shielding arises because z's firm is less affected by losing the cost advantage in x's market as x was importing greater quantity due to its pre-existing PTA with z compared to no PTA between x and z.

(11) gives us the following proposition.

Proposition 2. *A country's previous PTA with non-member country reduces the decrease of its imports from that non-member country due to a new PTA with another country.*

4 Econometric framework

4.1 Traditional gravity equation

The most commonly used framework to examine the trade volume effects of PTAs is the gravity equation:

$$
\begin{aligned}
ln(T_{ijt}) &= \alpha_0 + \alpha_1 lnY_{it} + \alpha_2 lnY_{jt} + \beta\mathbf{X}_{ijt} \\
&+ \gamma_1 PTA_{ijt} + \gamma_2 TD_{ijt} + \mu_t + \omega_{ij} + \epsilon_{ijt} \qquad (12)
\end{aligned}
$$

where T_{ijt} is the *import* by country i from country j at time t; PTA_{ijt} is a dummy taking a value of one if i and j are part of at least one PTA at time t and zero otherwise[4]; $TD_{ijt} = \sum_{k \neq j} PTA_{ikt}$ is the conventional trade diversion measure, constructed as the number of PTAs country i has signed with some third country $k \neq j$ at time t; Y is real GDP measured in purchasing power parity (PPP) terms; $\mathbf{X}$ is a vector of other determinants, such as distance, common language, GATT/WTO membership etc; μ_t represents any unobserved global trend in trade and aggregate shocks in each year; ω_{ij} is the unobserved country-pair heterogeneity that affects the likelihood of PTA, such as cultural, historical or political ties; and ϵ_{ijt} is the error term. In general, the literature suggests γ_1, which indicates the change in intra-bloc trade, to be positive while γ_2, which represents the change in extra-bloc trade, to be negative.[5]

Anderson and van Wincoop (2003) argue that omission of the multilateral trade resistance terms, in which trade barriers have a larger impact on relatively small countries, could lead to bias estimations. They suggest to employ importer-year and exporter-year FEs to allow for such time varying country heterogeneity. However, at the presence of CTFEs, it is impossible to identify the trade creation and diversion effects simultaneously due to perfect multicollinearity. This is because, PTA_{ijt} plus TD_{ijt} is equal to the total number of PTA membership country i has at time t, which is perfectly correlated to the importer-time FEs. However, when we quantify the cross PTA effects[6] over time, it is essential to include both PTA_{ijt} and TD_{ijt} to avoid omitted variable bias. To overcome this problem, we propose to introduce two-year CTFEs instead:

$$
\begin{aligned}
ln(T_{ijt}) &= \alpha_0 + \beta\mathbf{X}_{ijt} + \gamma_1 PTA_{ijt} + \gamma_2 TD_{ijt} \\
&+ \omega_{ij} + u_{it} + v_{jt} + \epsilon_{ijt} \qquad (13)
\end{aligned}
$$

where u_{it} and v_{jt} are respectively the importer-time and exporter-time FEs, and they are allowed to vary for every two years, i.e. $u_{it} = u_{i,t+1}$ and $v_{jt} = v_{j,t+1}$ for $t = 1,3,5....$[7] We argue that this treatment is sufficient because the multilateral trade resistance terms, being a function of prices, are unlikely to fluctuate much on an annual basis. This specification will allow us to identify both the trade creation and diversion effects as long as there are sufficient changes of PTA_{ijt} and TD_{ijt} within the two-year window. We will show in the empirical section that the results are not sensitive to the use of CTFEs of different durations.

As an alternative to treating CTFEs in (13) as dummy variables, we also directly model them using the CRE approach in Chamberlain (1980)and Mundlak (1978):

[4] If the two countries are part of more than one PTA at time t, we only count it as one because extra PTA is redundant as far as the same two countries are concerned.

[5] Kowalczyk (2000) points out that a member country may increase the volume of trade with a non-member country due to income effect, or the complementarity of goods traded between members and non-members.

[6] We use the terms cross PTA effect and interactive effect between PTAs interchangably.

[7] Since CTFEs vary only every two years, the variable for the time FEs, μ_t, does not drop out.

$$u_{it} = \overline{\mathbf{W}}_{it}\xi_1 + a_{it};\ v_{it} = \overline{\mathbf{W}}_{jt}\xi_2 + b_{it} \quad (14)$$

where $\overline{\mathbf{W}}_{it} = \frac{1}{n}\sum_j \mathbf{W}_{ijt}$, $\overline{\mathbf{W}}_{jt} = \frac{1}{n}\sum_i \mathbf{W}_{ijt}$, $\mathbf{W} = (\mathbf{X}, PTA, TD)$, and a_{it} and b_{it} are error terms. That is, we model u_{it} by averaging each covariate that varies in all three dimensions ($i \times j \times t$) across all partner countries j, and likewise model v_{jt} by averaging each covariate across all countries i. In addition to $\mathbf{X}_{ijt}$ in the original trade volume regression, we also include $ln(\frac{\text{trade deficit}_{ijt}}{GDP_{it} \cdot GDP_{jt}})$,[8] $ln(Income_{it} \cdot Income_{jt})$ and PTA_{ijt} to control for CTFEs.

These averaged variables $\overline{\mathbf{W}}_{it}$ and $\overline{\mathbf{W}}_{jt}$ are then used as separate regressors in the model:

$$\begin{aligned} ln(T_{ijt}) &= \alpha_0 + \alpha lnY_{it} + \alpha_2 lnY_{jt} + \beta\mathbf{X}_{ijt} + \gamma_1 PTA_{ijt} \\ &\quad + \gamma_2 TD_{ijt} + \omega_{ij} + \overline{\mathbf{W}}_{it}\xi_1 + \overline{\mathbf{W}}_{jt}\xi_2 + a_{it} + b_{jt} + \epsilon_{ijt} \end{aligned} \quad (15)$$

The CRE method makes use of the assumption that, once we have controled for CTFEs with $\overline{\mathbf{W}}_{it}$ and $\overline{\mathbf{W}}_{jt}$, a_{it} and b_{jt} are uncorrelated with any covariates in (15) and thus do not cause any endogeneity problems.

5 Data

We employ a panel data of 152 countries, all are World Trade Organization (WTO) members as in 2007 (details in appendix). Out of all country-pairs, 8,455 have positive bilateral trade in 1980 and the number increased to 15,232 by 2007.[9] Data on nominal bilateral trade flows are drawn from the IMF's Direction of Trade Statistics, data on nominal GDP and GDP per capita are drawn from the Penn World Table (PWT) 7.0, and data on GDP deflator are drawn from the U.S. Department of Commerce's Bureau of Economic Analysis. PTA data are constructed from Regional Trade Agreements Information System (RTA-IS) of the World Trade Organization (WTO) and data on GATT/WTO membership are also drawn from the WTO website. Data on distance, common language, common colony, common legal origin and adjacency are from CEPII.

There are three types of PTAs: customs union (CU), free trade agreement (FTA), and partial scope agreements (PSA), and the first two of which form our measure of PTA.[10] Table 1 reports the summary statistics of a number of covariates commonly seen in the gravity equation and a few others specific to the current study. Share borders, common language, common colony, and common legal origins are dummies variables. Among the 340,629 (time-specific) country-pairs with positive bilateral trade, 31,703 pairs or 9.3% have at least one PTA. There are substantial differences in the mean and standard deviation of the covariates between country-pairs with and without PTAs. This suggests the formation of PTA may be closely related to country and country-pair specific characteristics. Figure 6 in appendix depicts the time trend of the PTA

[8] When trade deficit is negative, $-ln(\frac{-tradedeficit_{ijt}}{GDP_{it} \cdot GDP_{jt}})$ is used instead to preserve the sign.

[9] Note that as we use the unidirectional bilateral import data, each country-pair appears twice a year.

[10] We exclude PSA because the agreements by PSA cover only the part of products unlike CU and FTA. Currently, 35 PSAs come into force which is around 7% of the total PTAs.

Table 1: Summary statistics of the data: Country-pairs with positive trade

	Whole sample		Pairs with PTA		Pairs w/o PTA	
	obs=340,629		obs=31,703		obs=308,926	
	Mean	S.D	Mean	S.D	Mean	S.D
log T_{ij}	14.81	3.77	17.12	3.92	14.58	3.68
Real GDP	294.9	1016.6	249.9	702.0	299.9	1043.4
log($Distance_{ij}$)	8.65	.83	7.34	.89	8.79	.70
share borders	.026	.160	.147	.354	.014	.117
common language	.175	.380	.295	.456	.163	.369
common colony	.100	.300	.206	.405	.089	.285
common legal origin	.337	.473	.425	.494	.328	.469
PTA_t	.093	.291				
TD_t	13.16	20.27	37.18	48.09	10.69	12.27

*Note: T_{ij} (bilateral trade volume) and real GDP are in million of constant 2000 US dollars. These variables are used in the benchmark regression. Summary statistics are calculated with 152 countries in appendix.

membership. Since the early 1990s, the number of country-pairs with PTAs increases dramatically, almost doubling in the last 25 years. Figure 7 in appendix illustrates the average value of the trade diversion variable defined as the number of PTAs signed between the exporting country and the third party. It has increased over time along with the sharp rise in PTAs, increasing from five in 1980 to more than 20 in 2006.

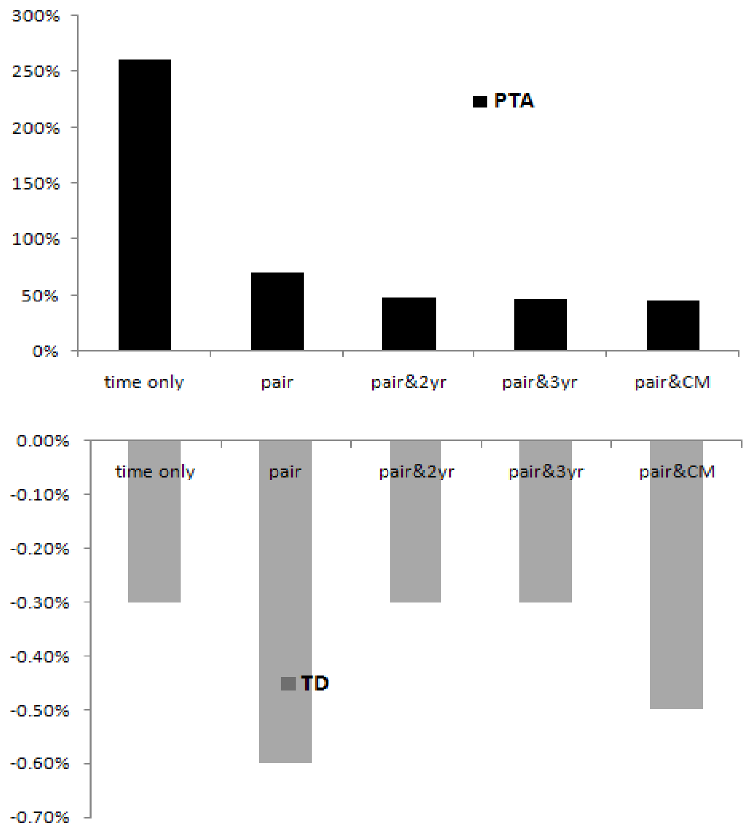
6 Results

We first estimate the model using OLS. Since there are a large number of zero observations for bilateral trade, we deploy a standard practice of using $ln(T_{ijt}+1)$ as the dependent variable, e.g. as in Liu (2009) and Roy (2011).[11] Estimated results are reported in Table 2 and illustrated in Figure 7. TD_{ijt} is not added in the first four columns. Each column is different in terms of FEs and, correspondingly, other control variables. The estimated coefficients of both PTA_{ijt} and TD_{ijt} are statistically significant at the 1% level in all estimations. With time fixed effects (TFEs) only, as shown in column (1), a PTA is estimated to increase trade between member countries by 218% ($e^{1.158}$=3.18). The impact of a PTA on bilateral intra-bloc trade flows, however, decreases substantially to 49% in column (2) when CPFEs are included. This implies that unobserved time-invariant heterogeneity (e.g. historical, cultural or political ties) that correlates with both the the formation of a PTA and bilateral trade flows tends to bias the PTA coefficient upward.

We further add CTFEs in columns (3) and (4). The difference between the two is that, CTFEs are allowed to vary every year in column (3) but only every two years in column (4). The coefficients on PTA are very similar (49% and 48% increase respectively in bilateral trade flows). This implies that two-year CTFEs sufficiently capture most of the multilateral trade resistance and country-specific aggregate shocks.

[11] We include a dummy for the zero observations in all the linear regressions.

Figure 2: PTA effects on bilater trade, 1980-2007, 152 WTO countries



*Note: time only: year FEs only, pair: year and CPFEs, pair & 2yr: year, CPFEs and 2-year CTFEs, pair & 3yr: year, CPFEs and 3-year CTFEs, pair & CM: year, CPFEs and CTFEs. CM represents the CRE approach.

In columns (5) to (8) we add TD_{ijt} to the model. The estimated coefficient of PTA with TFEs only in column (5) is not much different from that in column (1). TD_{ijt} is significant statistically, but not economically in that a PTA decreases trade flows between a member and a non-member by only 0.4%. Inclusion of CPFEs in column (6) sees the impact of intra-bloc bilateral trade flows falling by more than two third (from 261% to 71%) while the trade diversion effect is still negligible (0.6%). In column (7), when both CPFEs and two-year CTFEs are added, the trade creation effect of a PTA declines further to 48%, and the trade diversion effect decreases to 0.3%. To examine if our specification to account for multilateral trade resistance is reliable, we reestimate the model using three-year CTFEs in column (8) and the Chamberlain-Mundlak method in column (9). In both cases quantitative and qualitative results remain the same as in column (7).

Table 2: PTA effects: trade creation and trade diversion

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PTA_t	1.158	.396	.399	.394	1.285	.535	.395	.389	.376
	(.039)	(.026)	(.029)	(.029)	(.044)	(.028)	(.029)	(.029)	(.029)
TD_t					-.004	-.006	-.003	-.003	-.005
					(.001)	(.001)	(.001)	(.001)	(.002)
Controls	A	B	C	C	A	B	C	C	C
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes	yes
CPFEs	no	yes	yes	yes	no	yes	yes	yes	yes
CTFEs	no	no	1-yr	2-yr	no	no	2-yr	3-yr	CRE
Year: 1980-2007, Number of observations=578,423									

*Note: Cluster (country pairs) robust standard errors are reported in parentheses. "A" includes $\ln(distance_{ijt})$, $\ln(Y_{it})$, $\ln(Y_{jt})$, commom language , common colony , border contiguous, common legal origin and WTO pair-membership dummies. "B" includes $\ln(Y_{it})$, $\ln(Y_{jt})$. "C" has no other extra control variable. CRE represents accounting for time varying unobserved heterogeneity by the , CRE approach.

6.1 Linear regression

To measure the cross PTA effects over time, we modify equation (13) into:

$$\begin{aligned} ln(T_{ijt}+1) &= \alpha_0+\beta\mathbf{X}_{ijt}+\gamma_1 PTA_{ijt}+\gamma_2 TD_{ijt} \\ &\quad +\gamma_3(PTA_{ijt}\times TD_{ij,t-1})+\gamma_4(TD_{ijt}\times PTA_{ij,t-1}) \\ &\quad +\omega_{ij}+u_{it}+v_{jt}+\epsilon_{ijt} \qquad (16) \end{aligned}$$

The term $PTA_{ijt}\times TD_{ij,t-1}$ captures the dilution effects of pre-existing PTAs of i on the trade creation effects of a new PTA between i and j, while $TD_{ijt}\times PTA_{ij,t-1}$ captures the shielding effects of a pre-existing PTA between i and j on the trade diversion effects of new PTAs between i and some third countries. Here γ_1 is a measure of the trade creation effect of the first PTA (i.e. when $TD_{ij,t-1}=0$), $\gamma_3 TD_{ij,t-1}$ the dilution effect and $\gamma_1+\gamma_3 TD_{ij,t-1}$ the net trade creation effect. Likewise, γ_2 is a measure of the trade diversion effect of the first PTA, $\gamma_4 PTA_{ij,t-1}$ the shield effect and $\gamma_2+\gamma_4 PTA_{ij,t-1}$ the net trade diversion effect. Here we expect $\gamma_3<0$ and $\gamma_4>0$. If the shielding effect is sufficiently large, one may observe zero net trade diversion effect. Since previous studies do not account for the shielding effect, what they measure is the net trade diversion effect, and that may be the reason why the typical finding of it is very small and sometime no even significantly different from zero. In other words, to the extent that the dilution and shielding effects are significant, neglecting them in the gravity model will give rise to omitted variable bias.

Table 3 presents the estimation results and Figure 3 shows the size of the various effects evaluated at the mean values of the variables. For the convenience of comparison, the odd numbered columns are duplications of the last five columns in Table 2 and the even numbered columns add the cross PTA terms. Again, each pair of columns are different in terms of the FEs and corresponding additional controls.

With the cross PTA terms, the estimated coefficient of PTA in the first row represents the change in imports for the members that do not have any pre-existing PTA, that is, the trade creation effect of the first PTA. In column (2) with TFEs only, the trade between members increases by 328%, which is 67 percentage points larger than the estimated impact in column (1). Controlling for CPFEs again reduces such impacts substantially. The first PTA creates intra-bloc trade by 68% in column (4), as compared to 71% in column (3). As we further add CTFEs, change in intra-bloc trade due to a country's first PTA decreases even further to 34% as shown in columns (6) and (8), while it slightly increases to 52% in column (10) as compared to 46% in column (9) when the Chamberlain-Mundlak method is used to control for CTFEs.

In even numbered columns, the coefficient of TD_{ijt} indicates the change in trade flows between countries i and j due to the formation a PTA between country i and some third countries when i and j do not have a PTA. With TFEs only, a PTA is estimated to *increase* imports from non-member countries by 0.1% as shown in columns (2), in contrast to the trade diversion hypothesis.[12] The positive sign for TD_{ijt} , however, is reversed back to negative in column (4) in

[12] As pointed out by Kowalczyk (2000), PTAs may affect extra-bloc trade positively as they increase income in member countries or imported goods from insiders and outsiders of a bloc are complementary, or in this case it is simply biased because we do not account for the CPFEs and/or TFEs.

line with the previous literature, once we control for the endogeneity of PTA with CPFEs. A PTA is now estimated to reduce extra-bloc trade by about 0.7%. The estimated coefficients of TD_{ijt} remain negative and the impact turns out to be -0.7% and -0.3% with the additional CTFEs in columns (6) and (8) respectively, and -0.4% in column (10).

The coefficient of $PTA_t \times TD_{t-1}$ represents the additional change in intra-bloc trade flows for a new PTA due to pre-existing PTAs. For every estimation, the coefficient is statistically significant and yields a negative sign as expected. This implies that late coming PTAs for a country would not increase intra-bloc trade flows as much as its first PTA, confirming the existence of the dilution effect. Although the coefficient of $PTA_t \times TD_{t-1}$ seems to be small, its effect on trade flows can be large as it is conditional on the value of TD_{t-1}, which can be large. As indicated in equation (16), at the presence of the dilution effect, the net effect of a PTA is given by $\gamma_1 + \gamma_3 TD_{ij,t-1}$. Accordingly, in column (2), pre-existing PTAs dilute the trade creation effect of a new PTA by about slightly less than a half, from 328% to 147% ($e^{1.455+(-.042)13.16}$=2.47, where 13.16 is the mean of TD). Comparing this with the 261% estimate in column (1), this implies that ignoring the interactive effects of PTAs will greatly exaggerate the intra-bloc trade flow effects.

When we add CPFEs in column (4), the net PTA effect decreases to 33%, which is 35 percentage points less than the case without the interactive terms. Further adding CTFEs in columns (6), (8) and (10) shows that in net terms a PTA is estimated to increase the bilateral trade by 18%, 17% and 23% respectively, about 16, 17, and 29 percentage points lower than the corresponding static estimates.

Likewise, the coefficient of $TD_t \times PTA_{t-1}$ represents the additional change in extra-bloc trade flows for a new PTA due to pre-existing PTAs. In all estimations, the term is positive as expected and statistically significant. This implies that late coming PTAs for a country would not reduce extra-bloc trade flows as much as its first PTA, confirming the existence of the shielding effect. The net trade diversion effect is calculated as $\gamma_2 + \gamma_4 PTA_{ij,t-1}$. In column (2), with TFEs only, average extra-bloc trade is estimated to increase by 0.4% ($e^{.001+(.034).093}$=1.004, where .093 is the mean of PTA). Controlling for CPFEs in column (4), the trade flows between a member and non-member are estimated to fall by 0.5%, compared to 0.6% if we do not include the interaction term in column (3). The coefficient of TD in the second row of column (4) now represents the trade diversion effect of the first PTA for a country, which suggests a reduction of extra-bloc trade flows by 0.7%. This means that trade is 0.1 percentage point less diverted if a country has been previously engaged in other PTAs. In columns (6), (8) and (10) with CPFEs and CTFEs, average PTA is estimated to decrease the bilateral trade between a member and non-member by 0.6%, 0.2% and 0.3% respectively.

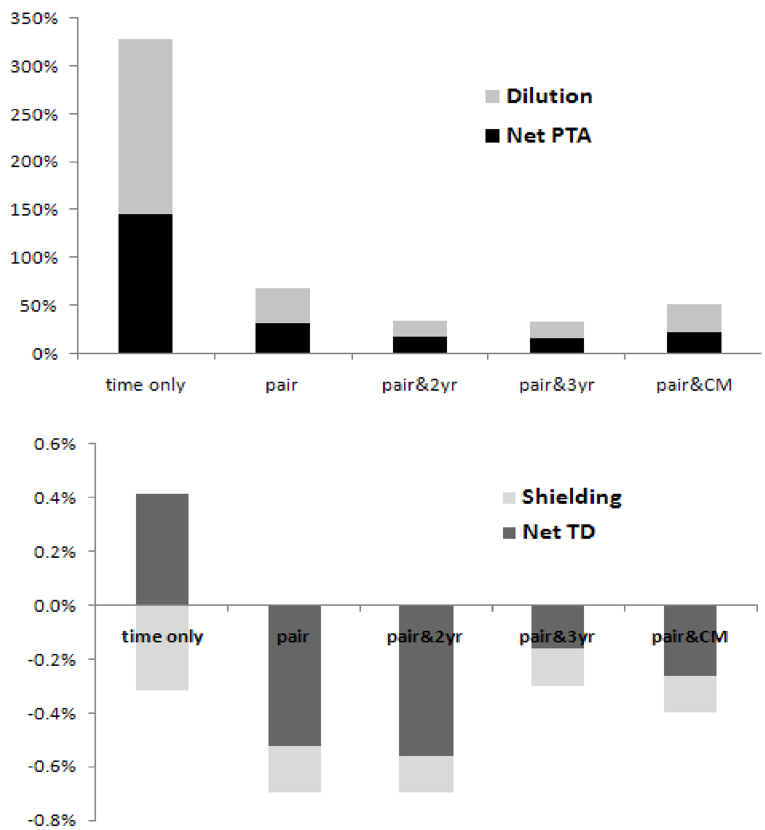
In sum, omitting either CPFEs or CTFEs severely biases the trade creation and diversion effects. For the estimates with all the fixed effects, the trade creation effect of the first PTA is 34% and the trade creation effect with the dilution effect is 16%. This implies that the dilution effect reduces trade creation by as many as 18 percentage points. On the contrary, both the trade diversion and shielding effects are economically negligible albeit statistically significant.

Table 3: OLS estimation of the PTA effects: dilution and shielding effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PTA_t	1.285	1.455	.535	.519	.395	.295	.389	.290	.376	.418
	(.044)	(.053)	(.028)	(.034)	(.029)	(.039)	(.029)	(.039)	(.029)	(.035)
TD_t	-.004	.001	-.006	-.007	-.003	-.007	-.003	-.003	-.005	-.004
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.002)	(.003)
$PTA_t \cdot TD_{t-1}$		-.042		-.018		-.010		-.010		-.016
		(.002)		(.001)		(.001)		(.001)		(.001)
$TD_t \cdot PTA_{t-1}$		.034		.019		.015		.015		.015
		(.002)		(.001)		(.001)		(.001)		(.001)
Controls	A	A	B	B	C	C	C	C	C	C
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
CPFEs	no	no	yes	yes	yes	yes	yes	yes	yes	yes
CTFEs	no	no	no	no	2-yr	2-yr	3-yr	3-yr	CRE	CRE
Year: 1980-2007, Number of observations=557,700										

*Note: Cluster (country pairs) robust standard errors are reported in parentheses. "A" includes $\ln(distance_{ijt})$, $\ln(Y_{it})$, $\ln(Y_{jt})$, commom language , common colony , border contiguous, common legal origin and WTO pair-membership dummies. "B" includes $\ln(Y_{it})$, $\ln(Y_{jt})$. "C" has no other extra control variable. CRE represents accounting for time varying unobserved heterogeneity by the CRE approach.

Figure 3: OLS estimates: dilution and shielding effects



*Note: time only: year FEs only, pair: year and CPFEs, pair & 2yr: year, CPFEs and 2-year CTFEs, pair & 3yr: year, CPFEs and 3-year CTFEs, pair & CM: year, CPFEs and CTFEs. CM represents the CRE approach.Net PTA is $exp(\gamma_1 + \gamma_3 \cdot \overline{TD})$ -1, and Dilution is PTA(exp(γ_1) − 1)-NET PTA. Net TD is $exp(\gamma_2 + \gamma_4 \cdot \overline{PTA})$ -1, and Shielding is TD($exp(\gamma_2) - 1$)-NET TD.

6.2 Heckman's two-stage estimation: Accounting for self-selection and the extensive margin of trade

In previous sections, we use $ln(T_{ijt}+1)$ as our dependent variable to include zero bilateral trade observations. However, this is an arbitrary way of treating zero values in the dependent variable. In this section, we apply a generalized gravity equation that accounts for both self-selection and the extensive margin changes due to firm heterogeneity following the two-stage Heckman (1979) procedure to control for self-selection and the Helpman et al. (2008) procedure to control for the extensive margin.

6.2.1 Two-stage estimation model

We obtain Heckman (1979) correction for self-selection of trade by estimating the following probit model:

$$\begin{aligned} Pr(T^*_{ijt}=1|\mathbf{M}_{ijt}) &= \alpha_0+\alpha_1 lnY_{it}+\alpha_2 lnY_{jt}+\beta_1\mathbf{X}_{ijt}+\beta_2\mathbf{Z}_{ijt} \\ &\quad +\gamma_1 PTA_{ijt}+\gamma_2 TD_{ijt}+\gamma_3(PTA_{ijt}\times TD_{ijt-1}) \\ &\quad +\gamma_4(TD_{ijt}\times PTA_{ijt-1})+\mu_t+\epsilon_{ijt} \end{aligned} \tag{17}$$

where the dependent latent variable T^*_{ijt} is equal to zero if $T_{ijt}=0$ and one if $T_{ij,t}>0$, $\mathbf{M}_{ijt}$ is a vector of all observed variables, and is a vector of excluded variables in the bilateral trade flows equation.

The exclusion restrictions require variables in $\mathbf{Z}_{ijt}$ to be statistically significant in determining whether two countries trade each other, but not statistically significant in determining their trade flows if they trade. Based upon availability of data, our potential exclusion restriction variables include religion as in Helpman et al. (2008)[13], costs in relation to infrastructure (Magee and Massoud, 2011)[14], and annual event count of riots and violent demonstrations (Magee and Massoud, 2011)[15]. The religion data are available for only two time points (1970 and 2000) thus we extrapolate them for other unavailable years.[16] Costs in relation to infrastructure are also available for the limited time period. For example, one of the variables, waterways per square kilometer of land area are available for the time period between 1992 and 2004. We construct the variable by multipling a pair countries' waterways for available time points and extrapolate it for the other time points.[17] It turns out that both religion and costs in relation to infrastructure by waterways satisfy the exclusion restrictions.

[13] The way to construct the variable "religion" is explained in appendix in Helpman et al. (2008).

[14] We use the following four variables: (i) kilometer (km) of waterways per square km of land area, (ii) km of railways per square km of land area, (iii) km of highways per square km of land area, and (iv) airports per square km, to calculate proxy variables for fixed trade cost. For each variable, we average the values of import-country and export-country. The data are available at http://www.facstaff.bucknell.edu/cmagee/.

[15] We think it may be a potential excluded varilable becuase if a country is politically or socially unstable, it is too costly or risky for traders to enter the market, but once they enter, the trade volume would be determined by economic factors instead.

[16] We use the 1970 data for years before 1985, the mean of 1970 and 2000 for years between 1986 and 1995 and 2000 data for 1996 onward.

[17] We use the 1992 data for years before 1992 and 2004 data for 2004 onward.

In the second stage, the trade flows equation to be estimated is given by:

$$\begin{aligned} ln(T_{ijt}) &= \alpha_0 + \alpha_t + \alpha_{ij} + \alpha_1 ln(Y_{it} + \alpha_2 lnY_{jt} + \beta \mathbf{X}_{ijt} \\ &+\gamma_1 PTA_{ijt} + \gamma_2 TD_{ijt} + \gamma_3 (PTA_{ijt} \times TD_{ijt-1}) \\ &+\gamma_4 (TD_{ijt} \times PTA_{ijt-1}) + \gamma_5 IMR_{ijt} (\text{or } \gamma_5 \Phi^{-1}(\hat{PR})) \\ &+\omega_{ij} + u_{it} + v_{jt} + \epsilon_{ijt} \end{aligned} \quad (18)$$

where IMR is the inverse mills ratio (IMR) obtained from (17), and $\hat{PR}$ is the predicted probablity of bilateral trade corrected for the extensive margin following Helpman et al. (2008).

Thus, in equation (18), bias due to self-selection of positive trade is controlled by IMR_{ijt} and bias due to the factors that affect both PTAs and the firm level extensive margin is controlled for by $\Phi^{-1}(P\hat{R}_{ij,t})$. [18]

6.2.2 Estimation results

Table 4 and Figure 4 report the results of two-stage estimations where waterways are used for the excluded variable.[19] All the coefficients are statistically significant. The first three columns replicate the bias decomposition in Helpman et al. (2008) using the CRE approach to control for time varying unobserved heterogeneity, the next three columns control for CPFEs, and the last three columns control for both. Columns (1), (4), and (7) report the benchmark regression estimations. Columns (2), (5) and (8) show simple linear correction for unobserved factors that affect the extensive margin of trade by adding $\Phi^{-1}(IM\hat{R}_{ij,t})$ as an additional regressor. In columns (3), (6) and (9), we account for sample selection using Heckman (1979) procedure.

A comparison of the first three columns shows how the ignorance of firm heterogeneity and sample selection biases the estimated coefficients when CPFEs are not added. As shown in column (1), a country's first PTA is estimated to increase its trade flows with members by 123% and to increase them with non-members by 0.8%. If we incorporate the dilution and shielding effects, intra-bloc trade effect of PTA is 68% and extra-bloc trade volume effect is 0.9 % . As we correct bias arising from firm heterogeneity in column (2), all the estimated coefficients decrease (in absolute value) except for the one representing the shielding effect. The impacts are calculated as 51% for the first PTA and 29% with the dilution effect, and 0.1% for trade diversion and 0.2% with the shielding effect. In column (3) we see that the results with Heckman correction are very similar to those from column (1). These findings support the argument of Helpman et al. (2008) that accounting for firm heterogeneity reduces biases while accounting for sample selection does not.

When we incorporate CPFEs without accounting for time varying unobserved heterogeneity, however, the estimated coefficients become very similar to one another as shown in columns

[18]As shown in Helpman et al. (2008), instead of adding $\Phi^{-1}(IM\hat{R}_{ij,t})$, we can add the regulation costs as a proxy for the fixed costs of exporting to control for firm heterogeneity. However, using the regulation costs data which is available from Djankov et al. (2002) causes a substantial drop-off in the number of obeservations. SeeHelpman et al. (2008) for more details.

[19]Since religion is only available for two periods, we provide the results from waterways.

(4), (5) and (6). This implies that CPFEs correct for the majority of biases due to sample selection and firm heterogeneity.[20] Both the trade creation and dilution effects are reduced, with about 40 to 50 % increase in intra-bloc trade for the first PTA, and around 22 to 28 % rise on average after incorporating the dilution effect. The impact on extra-bloc trade for the first PTA is estimated to 1.6 % in columns (4) and (5) and 1.3% in columns (6), and such impact declines to 1.4% and 1.1% respectively due to the shielding effect.

Estimations with both CPFEs and CTFEs again produce similar coefficients across columns (7), (8) and (9). The impact of the first PTA in columns (7), (8) and (9) is estimated to be 34%, 43%, and 43% respectively, and after taking into account the dilution effect, a PTA increases trade flows between members by 16%, 22% and 21% respectively. On the other hand, trade flows between a member and a non-member is expected to fall by about 1% for the first PTA, and the shielding effect 'save' about0.1% to0.3% of extra-bloc trade flows that would have been diverted.

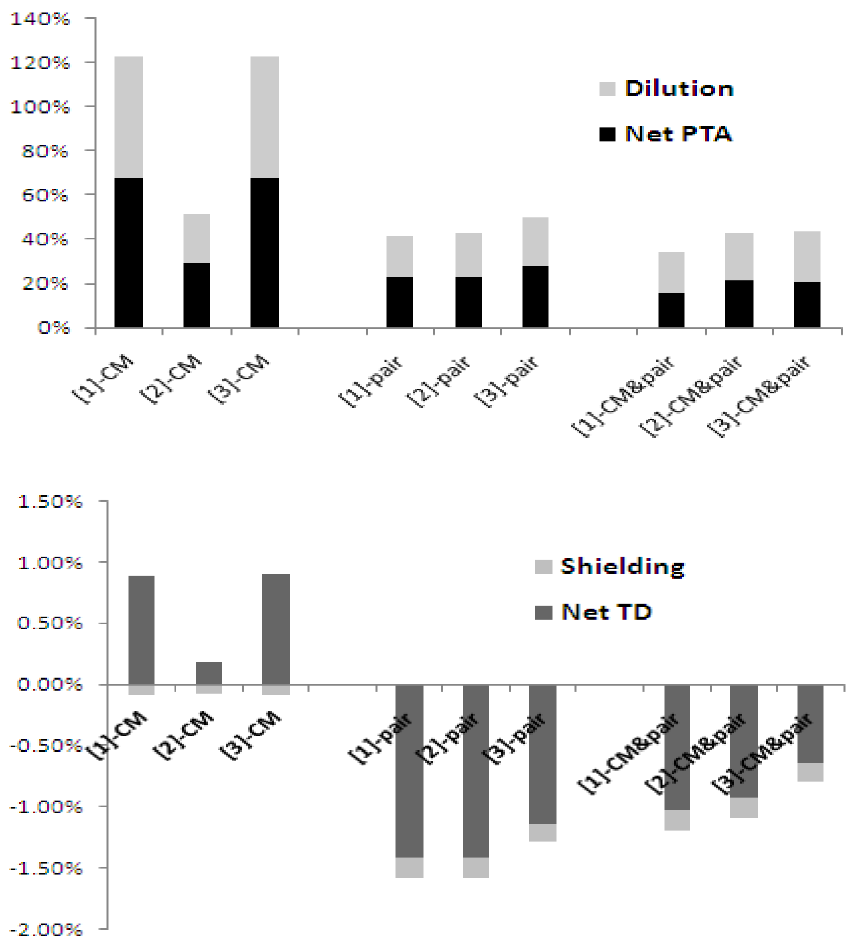
[20]This is possibly because we use (the extrapolated) waterways which do not have much variation over time, and thus CPFEs may account for most of unobserved heterogeneity which are captured by IMR_{ijt} and $\Phi^{-1}(IM\hat{R}_{ij,t})$.

Table 4: Estimates of dilution and shielding effects: Bias decomposion by Heckman's two-stage estimations

	1980-2007, 152 WTO member sample (obs=352,836)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PTA_t	.800	.415	.800	.344	.355	.406	.293	.355	.359
	(.060)	(.082)	(.060)	(.036)	(.045)	(.037)	(.036)	(.044)	(.038)
TD_t	.008	.001	.008	-.016	-.016	-.013	-.012	-.011	-.008
	(.001)	(.002)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
$PTA_t \cdot TD_{t-1}$	-.023	-.013	-.023	-.011	-.012	-.013	-.012	-.013	-.014
	(.002)	(.003)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
$TD_t \cdot PTA_{t-1}$	.008	.008	.009	.017	.017	.015	.016	.017	.015
	(.002)	(.002)	(.002)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
Controls	A	A	A	B	B	B	C	C	C
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes	yes
CPFEs	no	no	no	yes	yes	yes	yes	yes	yes
CTFEs	CRE	CRE	CRE	no	no	no	CRE	CRE	CRE
Firm heterogeneity	no	yes	no	no	yes	no	no	yes	no
IMR correction	no	no	yes	no	no	yes	no	no	yes

*Note: Cluster (country pairs) robust standard errors are reported in parentheses. "A" includes $\ln(distance_{ijt})$, $\ln(Y_{it})$, $\ln(Y_{jt})$, commom language , common colony , border contiguous, common legal origin and WTO pair-membership dummies. "B" includes $\ln(Y_{it})$, $\ln(Y_{jt})$. "C" has no other extra control variable. CRE represents accounting for time varying unobserved heterogeneity by the the CRE approach. IMR means that we add IMR_{ijt} as an additional regressor. Firm heterogeneity means that we add $\Phi^{-1}(I\hat{MR}_{ijt})$ as an additional regressor. .

Figure 4: Dilution and shielding effects: Heckman's two-stage estimations



*Note: From the left, the first three bars represent the replication of two-stage estimates of Helpman et al. (2008). The next three bars represent the estimates with CPFEs but without accounting for time varing unobserved heterogeneity. The last three bar show the estimates with both CPFEs and CTFEs. [2] is obtained with additional controlling for the extensive margin and [3] is obtained with additional controlling for self-selection. Net PTA is $exp(\gamma_1 + \gamma_3 \cdot \overline{TD})$ -1, and Dilution is PTA(exp$(\gamma_1) - 1$)-NET PTA. Net TD is $exp(\gamma_2 + \gamma_4 \cdot \overline{PTA})$ -1, and Shielding is TD($exp(\gamma_2) - 1$)-NET TD.

6.3 Conditional-Pseudo-Poisson-Maximum-Likelihood (CPPML) Estimation

So far our conclusions are drawn from the log-linear models where the dependent variables are either $ln(T_{ijt}+1)$ or $ln(T_{ijt})$. However, in the presence of heteroskedastic errors, Silva and Tenreyro (2006) show that log-linear model leads to severely biased estimates for the marginal effect of PTA. In this section we extend Heckman (1979)'s two-stage estimation with CPFEs and CTFEs to a CPPML estimator using (19) in the second stage. Our proposed CPPML estimator, together with CPFEs, CTFEs and firm heterogeneity correction terms, can avoid bias from heteroskedastic errors.

6.3.1 The model

The gravity model provides the following conditional expectation for trade flows:

$$
\begin{aligned}
E(T_{ijt}|\mathbf{W}_i) \;=\; & exp(\alpha_0+\alpha_1 lnY_{it}+\alpha_2 lnY_{jt}+\beta\mathbf{X}_{ijt} \\
& +\gamma_1 PTA_{ijt}+\gamma_2 PTD_{ijt}+\gamma_3(PTA_{ijt}\times TD_{ijt-1}) \\
& +\gamma_4(TD_{ijt}\times PTA_{ijt-1})+\omega_{ij}+u_{it}+v_{jt})\cdot E(\epsilon_{ijt}|\mathbf{W}_i)
\end{aligned} \tag{19}
$$

where it is assumed that $E(\epsilon_{ijt}|\mathbf{W}_i)=1$ and $\mathbf{W}_i$ includes all covariates on the right hand side of (19).

The Poisson regression model that accounts forunobserved heterogeneity with an additional regressor is provided in Greene (1994, 1995).[21]

$$
\begin{aligned}
E(T_{ijt}|\mathbf{W}_i) \;=\; & exp(\alpha_0+\alpha_1 lnY_{it}+\alpha_2 lnY_{jt}+\beta\mathbf{X}_{ijt} \\
& +\gamma_1 PTA_{ijt}+\gamma_2 PTD_{ijt}+\gamma_3(PTA_{ijt}\times TD_{ijt-1}) \\
& +\gamma_4(TD_{ijt}\times PTA_{ijt-1})+\gamma_5\Phi^{-1}(P\hat{R}_{ijt}) \\
& +\overline{\mathbf{X}}_{it}\boldsymbol{\delta_1}+\overline{\mathbf{X}}_{jt}\boldsymbol{\delta_2})
\end{aligned} \tag{20}
$$

where the firm heterogeneity correction term, $\Phi^{-1}(P\hat{R})$ is obtained from the probit model (17) and the CRE approach with the assumptions of $E(a_{it}|\mathbf{W}_i)=1$ and $E(b_{jt}|\mathbf{W}_i)=1$. However, the PPML estimator for (20) does not control for CPFEs which are crucial to correct bias in the estimation of the PTA effects. As we use conditional poisson regresssion model control for CPFEs, our estimation is as follow:

$$
\begin{aligned}
E(T_{ijt}|\mathbf{W}_i,\sum_{t=1} T_{ijt}) \;=\; & exp(\alpha_0+\alpha_1 lnY_{it}+\alpha_2 lnY_{jt}+\beta\mathbf{X}_{ijt} \\
& +\gamma_1 PTA_{ijt}+\gamma_2 PTD_{ijt}+\gamma_3(PTA_{ijt}\times TD_{ijt-1}) \\
& +\gamma_4(TD_{ijt}\times PTA_{ijt-1})+\gamma_5\Phi^{-1}(IM\hat{R}_{ijt}) \\
& \overline{\mathbf{X}}_{it}\boldsymbol{\delta_1}+\overline{\mathbf{X}}_{jt}\boldsymbol{\delta_2})
\end{aligned} \tag{21}
$$

[21] As implied by the results in Helpman et al. (2008) and our own estimation results in section 4.2, once we control for both CPFEs and CTFEs, additional control of self-selection of trade by Heckman's IMR does not further eliminate bias for PTA effect estimates. Thus, we do not control for self-selection in the estimation of Poisson regression models.

. This entails us to eliminate ω_{ij} in (19) by conditioning on $\sum_{t=1} T_{ijt}$, using the result in Hausman et al. (1984). Once we condition the log-likelihood function of (19) on $\sum_{t=1} T_{ijt}$ and, given that the error structure of CTFEsis such that $E(a_{it} + b_{jt} + \epsilon_{ijt}|\mathbf{W}_i) = 1$ based on the CRE approach and the conditional expectation of (19) is correct, the CPPML estimator of (21) is consistent. The CPPML estimator with firm heterogeneity correction is also consistent since it only requires conditional expectation to be correct but not second moments (Gourieroux et al. (1984)).

6.3.2 Estimation results

Table 5 and Figure 5 provide the CPPML estimation results.[22] When neither CPFEs nor CTFEs are used (i.e., the CPPML estimator is the PPML estimator), as shown in column (1), intra-bloc trade is estimated to increase by 148% due to the first PTA and 133% after incorporating the dilution effect. Compared to the 328% increase with the log-linear model, the PPML estimation of the first PTA effect is much smaller (148%), implying severe bias in the log-linear model due to heteroskedastic errors. As reported in Silva and Tenreyro (2006), the coefficient of PTA shrinks in Poisson regressions compared to log-linear model regressions. In column (2), CPFEs are added using the CPPML method. The increases in trade flows between members declines to 22% with the initial PTA, and 19% with the dilution effect. This confirms that it is crucial to apply the CPPML estimator, instead of the PPML one. Column (3) shows the result when both CPFEs and CTFEs are controlled for. The coefficient of PTA is slightly smaller than that in column (2). It shows that intra-bloc trade flows increase by 20% with the first PTA and 11% after incorporating the dilution effect. In columns (4) and (5), we further control for firm heterogeneity. The first PTA increases the intra-bloc trade by 39% with no CTFEs and 29% with CTFEs, and the trade creation effect after incorporating the dilution effect is 27% and 14% respectively. However, although the point estimates become larger after controlling for firm heterogeneity, once we take into account the standard errors, the estimates in columns (4) and (5) are not much different from those in columns (2) and (3) respectively.

Now we turn to the trade diversion and shielding effects. As shown in column (1), if we control for the time FEs only, trade flows between a member and a non-member are estimated to decrease by 0.7% in case of the first PTA, and 0.6% after incorporating the shielding effect. When we add CPFEs in column (2), extra-bloc trade is to increase by 0.1% in case of the first PTA but the coefficient is statistically insignificant, and 0.15% with the shielding effect. As we further add CTFEs in column (3), it increases by 0.5% with the first PTA but the coefficient is still statistically insignificant, and 0.6% with the shielding effect. Accounting for firm heterogeneity does not change the qualitative results. The trade diversion term is still positive and statistically insignificant, and the net trade diversion effect after incorporating the shielding effect is slightly larger with CTFEs and the coefficent becomes statistically more significant in relative terms.

In summary, the CPPML estimation confirms the results of log-linear model estimation in that the dilution and shielding effects are statistically and economically significant, but it finds that the trade diversion is neither statistically nor economically significant. Size-wise the dilu-

[22]Silva and Tenreyro (2011) show that the PPML estimator performs well even with a large number of zero observations in the dependent variable, and Westerlund and Wilhelmsson (2011) show similar results for the CPPML estimator.

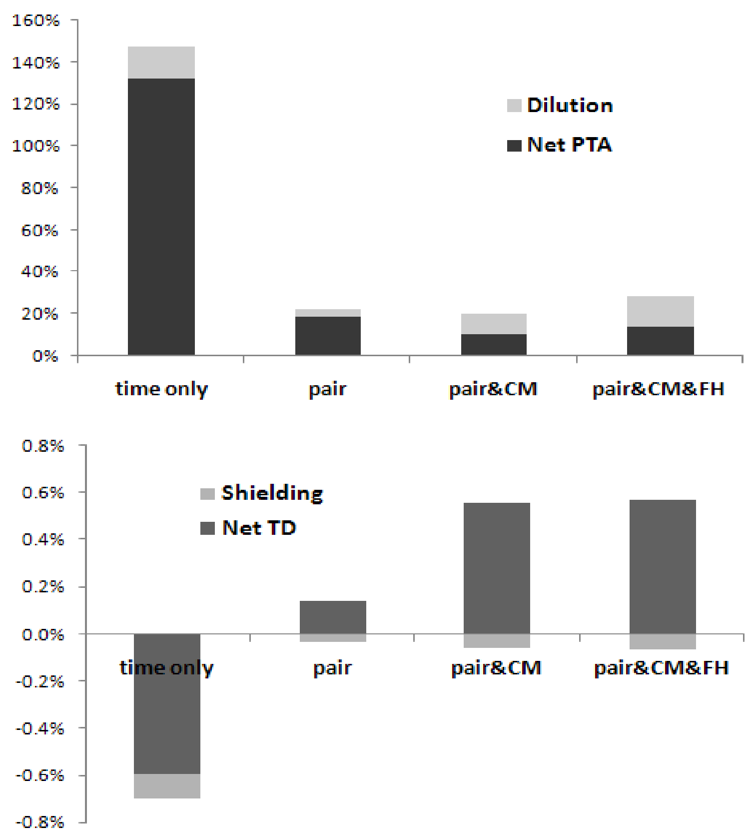
Table 5: Estimates of dilution and shielding effects: Bias decomposion by the CPPML model

	1980-2007, 152 WTO member sample				
	(1)	(2)	(3)	(4)	(5)
PTA_t	.907	.199	.181	.328	.251
	(.115)	(.059)	(.071)	(.054)	(.071)
TD_t	-.007	.001	.005	.001	.005
	(.002)	(.002)	(.004)	(.071)	(.004)
$PTA_t \cdot TD_{t-1}$	-.005	-.002	-.006	-.007	-.009
	(.003)	(.002)	(.003)	(.002)	(.003)
$TD_t \cdot PTA_{t-1}$	.011	.004	.006	.004	.007
	(.002)	(.002)	(.002)	(.002)	(.002)
Controls	A	B	C	B	C
Time FEs	yes	yes	yes	yes	yes
CPFEs	no	yes	yes	yes	yes
CTFEs	no	no	CRE	no	CRE
Firm heterogeneity	no	no	no	yes	yes

*Note: Cluster (country pairs) robust standard errors are reported in parentheses. "A" includes $\ln(distance_{ijt})$, $\ln(Y_{it})$, $\ln(Y_{jt})$, commom language , common colony , border contiguous, common legal origin and WTO pair-membership dummies. "B" includes $\ln(Y_{it})$, $\ln(Y_{jt})$. "C" has no other extra control variable. CRE represents accounting for time varying unobserved heterogeneity by the CRE approach.

tion effect is about a half of the trade creation effect when we control for both CPFEs and CTFEs. Additionally accounting for firm heterogeneity has little influence on the results.

Figure 5: Dilution and shielding effects: CPPML estimator



*Note: time only: year FEs only, pair: year and CPFEs, pair & CM: year, country-pair and country-time FEs (CRE approach). Net PTA is $exp(\gamma_1 + \gamma_3 \cdot \overline{TD})$ -1, and Dilution is PTA(exp(γ_1) − 1)-NET PTA. Net TD is $exp(\gamma_2 + \gamma_4 \cdot \overline{PTA})$ -1, and Shielding is TD($exp(\gamma_2) - 1$)-NET TD.

7 Conclusion

In this paper, we focus on the cross effects of PTA on bilateral trade flows. We develop and quantify two such effects—the (trade creation) dilution effect and the (trade diversion) shielding effect respectively. We base our empirical models on the gravity equation while accounting for various unobserved and omitted variables that could have caused estimation biases. We implement the log-linear model, Heckman (1979)'s two-stage and Helpman et al. (2008)'s firm heterogeneity correction procedures, and the CPPML method with CPFEs and CTFEs. . On top of controlling for CPFEs, we use two-year CTFEs or the CRE approach to circumvent the multicollinearity problem that derailed previous attempts in controlling for time varying unobserved heterogeneity when estimating both the trade creation and diversion effects simultaneously.

All our estimations show that PTAs create more trade between members. In spite of the strong evidence that the trade creation effect is diluted substantially by pre-existing PTAs, the net PTA effect on bilateral trade betweenmembers remains significant statistically and economically. As for the trade flows between members and non-members, the estimated trade diversion effect is very small. The shielding effect, which is found to be statistically significant, mitigates the decrease in extra-bloc trade flows such that the net trade diversion effect is even smaller.

Latest theoretical studies attempt to explain the recent surge of PTAs based on the trade diversion and shielding effects, e.g., Egger and Larch (2008) and Baier et al. (2011). They argue that one of the main incentives to seek for a PTA is to avoid trade diversion from other PTAs. Although our estimation results confirm the existence of the shielding effect, they cast doubt on their practical importance. While the positive intra-bloc trade effect of PTAs dominates the negative extra-bloc trade effect by far,both the trade diversion and shielding effects are very small in magnitude. Our results indicate that it is trade creation, not the mitigation of trade diversion, should be the major incentive in the formation of a PTA.

A Robustness check of the dilution and shielding effects

We replicate the estimations of Tables 3 and 4 with PTA_{ijt-1} and TD_{ijt-1} as additional regressors. The rationale is to avoid the interaction terms $PTA_{ijt} \times TD_{ijt-1}$ and $TD_{ijt} \times PTA_{ijt-1}$ in equation (16) from picking up the respectively individual effects of TD_{ijt-1} and PTA_{ijt-1}. Table 6 shows the estimation results of the dilution and shielding effects for the log-linear model. Table 7 shows the results after accounting for sample selection and firm heterogeneity. We can not replicate the Poisson estimation for Table 5 due to non-convergence problems with the CPPML estimation. As previously pointed out by **Silva and Tenreyro (2010, 2011)**, this non-convergence problems could happen when the Poisson model includes dummy variables, such as PTA_{ijt} and PTA_{ijt-1} in our case. As it can be seen from the two tables, including those two additional regressors has little impact on the previous findings.

Table 6: OLS estimates of the PTA trade effects: dilution and shielding effects

	(2)	(4)	(6)	(8)	(10)
PTA_t	1.293	.463	.296	.265	.354
	(.049)	(.033)	(.028)	(.033)	(.034)
TD_t	-.005	-.006	-.007	-.002	-.003
	(.001)	(.001)	(.001)	(.001)	(.001)
$PTA_t \cdot TD_{t-1}$	-.038	-.016	-.010	-.009	-.015
	(.002)	(.001)	(.001)	(.001)	(.001)
$TD_t \cdot PTA_{t-1}$	.030	.018	.015	.015	.013
	(.002)	(.001)	(.001)	(.001)	(.001)
Controls	A	B	C	C	C
Time FEs	yes	yes	yes	yes	yes
CPFEs	no	yes	yes	yes	yes
CTFEs	no	no	2-yr	3-yr	CRE
	Year: 1980-2007, Number of observations=557,700				

*Note: We number each column to be directly comparable to columns in Table 3. Cluster (country pairs) robust standard errors are reported in parentheses. "A" includes ln($distance_{ijt}$), ln(Y_{it}), ln(Y_{jt}), commom language , common colony , border contiguous, common legal origin and WTO pair-membership dummies. "B" includes ln(Y_{it}), ln(Y_{jt}). "C" has no other extra control variable. CRE represents accounting for time varying unobserved heterogeneity by the CRE approach.

Table 7: Estimates of dilution and shielding effects: Bias decomposion by Heckman's two-stage estimations

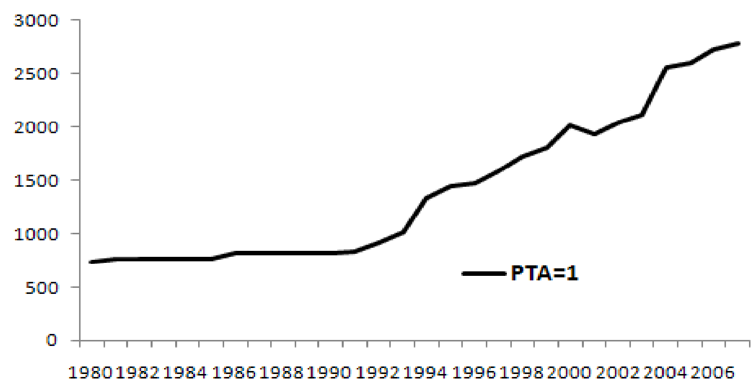
	1980-2007, 152 WTO member sample (obs=352,836)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PTA_t	.413	.052	.414	.312	.327	.368	.268	.333	.334
	(.053)	(.077)	(.054)	(.036)	(.045)	(.037)	(.037)	(.045)	(.039)
TD_t	.000	-.006	.000	-.012	-.012	-.008	-.009	-.008	-.004
	(.001)	(.002)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
$PTA_t \cdot TD_{t-1}$	-.014	-.005	-.014	-.010	-.011	-.012	-.010	-.012	-.013
	(.002)	(.003)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
$TD_t \cdot PTA_{t-1}$	-.003	-.003	-.002	.017	.016	.014	.016	.016	.014
	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
Controls	A	A	A	B	B	B	C	C	C
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes	yes
CPFEs	no	no	no	yes	yes	yes	yes	yes	yes
CTFEs	CRE	CRE	CRE	no	no	no	CRE	CRE	CRE
Firm heterogeneity	no	yes	no	no	yes	no	no	yes	no
IMR correction	no	no	yes	no	no	yes	no	no	yes

*Note: We number each column to be directly comparable to columns in Table 4. Cluster (country pairs) robust standard errors are reported in parentheses. "A" includes $\ln(distance_{ijt})$, $\ln(Y_{it})$, $\ln(Y_{jt})$, commom language , common colony , border contiguous, common legal origin and WTO pair-membership dummies. "B" includes $\ln(Y_{it})$, $\ln(Y_{jt})$. "C" has no other extra control variable. CRE represents accounting for time varying unobserved heterogeneity by the CRE approach. IMR means that we add IMR_{ijt} as an additional regressor. Firm heterogeneity means that we add $\Phi^{-1}(IM\hat{R}_{ijt})$ as an additional regressor.

Table 8: Lists of countires: 152 WTO members in 2007

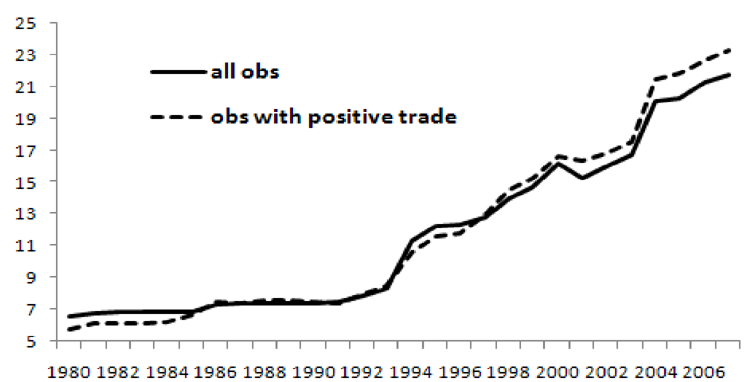
Albania	Denmark	Korea	Portugal
Angola	Djibouti	Kuwait	Qatar
Antigua and Barbuda	Dominica	Kyrgyz Republic	Romania
Argentina	Dominican Republic	Latvia	Rwanda
Armenia	Ecuador	Lesotho	St. Kitts and Nevis
Australia	Egypt	Lithuania	St. Lucia
Austria	El Salvador	Luxembourg	St. Vincent and Grenadines
Bahrein	Estonia	Macao	Saudi Arabia
Bangladesh	Fiji	Malagasy	Senegal
Barbados	Finland	Malawi	Serbia and Montenegro
Belgium	France	Malaysia	Sierra Leone
Belgium-Luxembourg	French Guiana	Maldive Islands	Singapore
Belize	Gabon	Mali	Slovakia
Benin	Gambia	Malta	Slovenia
Bolivia	Georgia	Mauritania	Solomon Islands
Botswana	German D. Rep.	Mauritius	South Africa
Brazil	German F. Rep	Mexico	Spain
Brunei	Ghana	Moldova	Sri Lanka
Bulgaria	Greece	Mongolia	Suriname
Burkina Faso	Grenada	Morocco	Swaziland
Burundi	Guatemala	Mozambique	Sweden
Cambodia	Guinea	Myanmar	Switzerland
Cameroun	Guinea-Bissau	Namibia	Tanzania
Canada	Guyana	Nepal	Thailand
Central African Republic	Haiti	Netherlands	Togo
Chad	Honduras	New Zealand	Tonga
Chile	Hong Kong	Nicaragua	Trinidad
China	Hungary	Niger	Tunisia
Colombia	Iceland	Nigeria	Turkey
Congo, DR	India	Norway	Uganda
Congo, Rep.	Indonesia	Oman	United Arab Emirates
Costa Rica	Ireland	Pakistan	United Kingdom
Côte d'Ivoire	Israel	Panama	United States of America
Croatia	Italy	Papua New Guinea	Uruguay
Cuba	Jamaica	Paraguay	Venezuela
Cyprus	Japan	Peru	Vietnam, Democratic Rep.
Czech Republic	Jordan	Philippines	Zambia
Czechoslavakia	Kenya	Poland	Zimbabwe

Figure 6: Number of observations for PTA=1



*Note: PTA=1 if both countries in a pair are engaged in the same PTA in each year.

Figure 7: Average value of trade diversion



*Note: The sample covers from 1980 to 2007.

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