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2020

September 2020

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Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
https://www.cesifo.org/en/wp
An electronic version of the paper may be downloaded
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CESifo *Working Paper No. 8553*

Gravity-Model Estimation with Time-Interval Data: Revisiting the Impact of Free Trade Agreements

Abstract

We challenge the common practice of estimating gravity equations with time-interval data in order to capture dynamic-adjustment effects to trade-policy changes. Instead, we point to a series of advantages of using consecutive-year data recognizing dynamic-adjustment effects. Our analysis reveals that, relative to time-interval data, the proposed approach avoids downward-biased effect estimates due to the distribution of trade-policy events during an event window as well as due to anticipation (pre-interval) and delayed (post-interval) effects, and it improves the efficiency of effect estimates due to the use of more data.

JEL-Codes: F100, F140.

Keywords: structural gravity, trade policy, free trade agreements, interval data.

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September 4, 2020

Highlights

- Time-interval data may lead to biased estimates of the short-run and long-run magnitudes of trade-policy effects.
- Time-interval data may lead to significant biases in the duration and timing of these effects.
- The effect of the FTAs begins few (about 3) years prior to their entry into force.
- The immediate/contemporaneous FTA effects are not statistically significant.
- The total time to reach the full impact of FTAs on trade is about 10 years.
- The effects of FTAs on international trade are positive but non-monotonic.
- The strongest FTA effects take place a few years after their entry into force.
- We identify 7 phases that characterize the long-run impact of FTAs on trade.

1 Introduction and Motivation

Knowing about the specifics of the dynamic adjustment of trade flows in response to trade policy is vital for academic work as well as policy making for the following reasons. First, adjustment processes entail that the short-run and the long-run responses of outcomes of interest differ. Second, they bear the danger that the responses are not measured in full due to the ignorance of anticipation effects or delayed effects which materialize after the sample period of analysis. Third, they may involve non-linear if not non-monotonic adjustment patterns of outcomes over time, which may be important to know and understand. In any case, the adjustment of economic outcomes to economic policy is typically not instantaneous and a proper characterization of the adjustment process (including its beginning, form, and duration) as well as the unbiased quantification of the short-run and long-run effects may be challenging. All of these arguments are important in the context of the responses of outcomes such as trade flows to the enforcement of free-trade areas as one of the key bilateral policy measures in international trade.

The modern empirical analysis of trade-policy effects on trade flows may be characterized as follows. First, Free Trade Agreements (FTAs) feature prominently as a policy instrument, because details about them (including their inception and content) are made available to the public by the World Trade Organization (WTO) for virtually all countries (and country pairs) in the world and the time period since after World War II. In comparison, other policy instruments such as tariffs or non-tariff barriers are much harder to collect and available for a much shorter sample period and cross section of parties they are applied by. Similarly, trade outcomes (values

and quantities at the aggregate and the product level) are available also for large cross-sections and long sample periods, which enables the use of time-series as well as cross-section data for economic analysis of FTA effects. Since both trade flows and FTAs can be measured at the country-pair level, the predominant approach to estimating direct responses makes use of the gravity equation of bilateral trade. Second, the availability of time-series and cross-section data on policy treatment and economic outcome together with the developments in econometric theory for such data permits the use of panel-data methods which are now the leading tool to use for parameter (and direct-response) estimation of FTAs on trade.

However, the very responses of trade to policy instruments such as FTAs is likely dynamic for various reasons. First, FTAs are typically announced before they come into force, which may induce a boost in (anticipated) firm value and associated investments (see Moser and Rose, 2014). Second, FTAs often involve phase-in periods for tariff- and non-tariff-barrier adjustments which means that their full trade-facilitation effect comes into play only years after their inception. Third, firms need time to adjust – their investments, their business network, etc. – so that there is a delay of their response to the materialized facilitation of trade flows. All of those aspects require a proper treatment in the analysis in order to obtain unbiased estimates of the (average) pattern of the adjustment process (its beginning and duration as well as its pattern) so that short-run, medium-run, and long-run effects of FTAs can be properly measured.

With regard to the use of panel-data methods to estimate gravity models in contexts where dynamic adjustment is important, Cheng and Wall (2005) note that

"[f]ixed-effects estimation is sometimes criticized when applied to data pooled over consecutive years on the grounds that dependent and independent variables cannot fully adjust in a single year's time." (Cheng and Wall, 2005, Footnote 8, p. 52). Also Trefler (2004), with specific reference to the analysis and quantification of FTA effects, criticizes the use of data that are pooled over consecutive years. Clearly, the use of fixed (country-pair) effects is motivated by the opportunity to control for all measured (e.g., geographical distance) and unmeasured time-invariant obstacles to and facilitations of bilateral trade. However, with dynamic adjustment processes present, there is a danger of relying on fixed-effects estimates where policy responses are only measured (allowed to materialize) contemporaneously with the inception of associated treatments: whereas pooling the data over longer time periods will lead to a convergence of the parameter estimates to the long-run responses, using the fixed-effects parameter estimates will lie somewhere in between the short-run and long-run responses (see Egger and Pfaffermayr, 2005).

To address such critiques and potentially avoid the associated biases, researchers have used panel data with time-intervals instead of ones based on consecutive years to estimate the direct responses (net of or before general-equilibrium adjustments) of trade flows to FTA membership. For example, Trefler (2004) uses 3-year intervals, Cheng and Wall (2005) and Baier and Bergstrand (2007) use 5-year intervals, and Olivero and Yotov (2012) experiment with 3- and 5-year interval data.

This paper challenges the common practice of using interval data to estimate the impact of trade policy effects in gravity equations. Instead, we argue in favor of specifications that employ all available data, i.e., data pooled over consecutive years,

but pay attention to dynamic adjustment processes. The motivation for our argument is threefold, whenever adjustment processes are present. First, time-interval data of trade and FTAs may lead to biased estimates of the short-run as well as the long-run effects during the pre-defined intervals due to the unequal spacing of FTAs during the considered time windows. With positive FTA effects and an accumulated adjustment, there will be a systematic downward bias in the long-run effect attributable to the time during the window. Second, the interval approach may suffer from averaged-out anticipation (pre-window) and delayed (post-window) effects. Either one of those will lead to a downward bias of both the short-run and the long-run responses. A third disadvantage from using time-interval data relative to annual data is that data are unnecessarily discarded so that parameters are less-precisely measured than possible. E.g., the sample size is reduced by 80 percent with 5-year intervals, by construction. Moreover, the aforementioned variation of the inception times of FTAs between the chosen interval boundaries is itself a source of parameter uncertainty and will show in inflated standard errors on the FTA parameters of interest.

We propose an approach which relies on annual data and pays attention to the non-linear response process. We illustrate the merits of this approach in a framework which respects the latest developments in the literature on estimating gravity models, focusing on the direct effects of FTAs on trade flows (net of general-equilibrium responses). The comparison between the results that we obtain with interval vs. consecutive-year estimating samples reveal that the use of interval data (i) leads to biases of the responses relative to the short-run and long-run (direct) effects as discussed above, and these biases pertain to during-interval when FTAs are newly

implemented as well as prior to and after such phases associated with anticipation and delay effects; (ii) the pattern of the response surface in time is not possible with larger-interval data and important phases of the process cannot be discerned with such an approach; (iii) the direct trade responses to FTAs is highly nonlinear, and the duration of the response adjustment takes altogether about 10 years on average.

We uncover several systematic patterns that characterize the impact of FTAs on trade among member countries. Consistent with the existing literature, we find that the cumulative effects of FTAs on international trade are positive and statistically significant. However, our estimates suggest that the evolution of these effects is highly nonlinear in time. The analysis reveals that the impact of FTAs begins about three years prior to their entry into force, possibly at the time when they are announced or signed. In addition, we find that immediate/contemporaneous effects of FTAs are actually not statistically significant and may even reduce some of the positive anticipation effects. According to our estimates, the main part of the positive impact of FTAs takes place between three and six years after their implementation, following a period of gradual initial adjustment. There are still positive and statistically significant effects of FTAs in our sample between seven and eight years after their entry into force. In combination with the estimated anticipation effects, these estimates imply that the full impact of FTAs on trade is reached about ten years after they start mattering in the anticipation period.

Using the full, annual, pooled estimating sample enables us to identify seven distinct and intuitive phases that characterize the evolution of the (direct) impact of FTAs on trade in our sample akin to the life cycle for products. The first phase,

labeled *'Pre-FTA Phase'*, covers the period of up to four years prior to the implementation of FTAs, and the agreements in our sample have no impact on trade among members during this period. The second phase, labeled *'Anticipation Phase'*, covers the period between one and three years prior to the entry into force, and we obtain positive and significant FTA estimates during this period. The third phase, dubbed *'Introduction Phase'*, covers the year of FTA entry into force, and our estimates reveal no statistically significant FTA effects in this period. We call the fourth phase *'Adjustment Phase'*. It covers the period of one to two years after the entry into force, and we obtain positive and statistically significant but small FTA estimates during this period. The fifth phase, covering the period between the third and the sixth year after implementation, is the *'High Growth Phase'*. This is the period when the effects of FTAs increase the most. We label the sixth phase the *'Slow Growth Phase'* because during this period (seven to eight years after entry into force) the impact of FTAs is still increasing but the increase is smaller than in the period before that. The final phase, labeled *'Maturity Phase'*, begins about eight years after an FTA's entry into force and from this phase onwards there are no additional associated trade effects. Then, an FTA may be said to have reached its full potential on average.

The remainder of the paper is organized as follows. Section 2 introduces our estimating equation and describes the data. Section 3 presents and analyzes our main findings. In Section 4, we summarize and attempt to generalize our results, and we discuss the broader implications of our findings. Section 5 concludes. The Data Appendix offers details on the countries and the free trade agreements in our estimating sample.

2 Estimating Equation and Data

We rely on the latest developments in the theoretical and in the empirical gravity literature to specify our econometric model as follows:[1]

$$\begin{aligned} X_{ij,t} &= \exp[\alpha FTA_{ij,t} + \sum_{s} \alpha_s FTA_{ij,t+s} + \sum_{k} \beta_k FTA_{ij,t-k}] \times \\ &\quad \exp[\sum_{t} \beta_t BRDR_{ij,t} + \gamma_{ij} + \psi_{i,t} + \phi_{j,t}] \times \varepsilon_{ij,t}, \quad \forall i, j, t. \end{aligned} \tag{1}$$

Here, $X_{ij,t}$ denotes valued bilateral trade flows from country i to j at time t in levels and, following the recommendation of Yotov et al. (2016) for the use of theory-consistent trade flows, $X_{ij,t}$ includes both international and intra-national trade flows observations. Following the recommendations of Santos Silva and Tenreyro (2006) and Santos Silva and Tenreyro (2011), one should abstain from log-transforming the model in (1) but estimate it with the Poisson Pseudo Maximum Likelihood (PPML) estimator, which accounts for heteroskedasticity in trade data and takes advantage of the information that is contained in zero trade flows. The parameters α, α_s and β_k are of particular interest here, as they measure the direct contemporaneous, leading (anticipation), and delayed (phasing-in or sluggish-adjustment) responses,

[1] As demonstrated by Arkolakis, Costinot and Rodríguez-Clare (2012), the structural estimating gravity equation can be derived from, and is therefore representative of, a very wide class of underlying micro-foundations. We refer the reader to Anderson (2011) and Costinot and Rodríguez-Clare (2014) for recent surveys of the theoretical gravity literature and to Head and Mayer (2014) and Yotov et al. (2016) for recent surveys of the empirical gravity literature. What is elemental is that, with time-indexed aggregate bilateral trade data, exporter-time and importer-time fixed effects should be included, as they control for endogenous price and income as well as other country-specific variables.

respectively, of country pairs' trade flows to the inception of an average FTA.[2] $FTA_{ij,t}$ is an indicator variable that takes a value of one when i and j are members of the same FTA in force at time t, and it is equal to zero otherwise. Following Wooldridge (2010) and Baier and Bergstrand (2007), the motivation for the inclusion of the first FTA lead from the estimating sample is that its estimate can be used to test for strict exogeneity, e.g., due to reverse causality. Our empirical analysis reveals that some of the FTA lead effects are actually significant and we argue that they should be accounted for explicitly in econometric specifications.

Equation (1) includes four sets of fixed effects. As is standard in the literature, we use exporter-time fixed effects ($\psi_{i,t}$) and importer-time fixed effects ($\phi_{j,t}$) to control inter alia for the unobservable exporter and importer multilateral resistances established by Anderson and van Wincoop (2003). These fixed effects will also absorb/control for any other country-time-specific characteristics that may impact bilateral trade on the exporter and on the importer side. In addition, following the recommendations of Baier and Bergstrand (2007) and Egger and Nigai (2015), we also employ country-pair fixed effects (γ_{ij}), which will absorb/control for all time-invariant bilateral trade costs and will mitigate endogeneity concerns with respect to our key policy variable of interest, $FTA_{ij,t}$. Finally, we follow Bergstrand, Larch and Yotov (2015) to account for common globalization effects with a set of time-varying border dummy variables.[3]

[2] We focus exclusively on the impact of FTAs for clarity and simplicity. This is consistent with the FTA analysis of Baier and Bergstrand (2007). The implications of our analysis most likely extend to other policy variables, e.g. WTO membership, EU membership, etc.

[3] These are created on the basis of an indicator for external (foreign) sales as opposed to sales from i to i, $BRDR_{ij}$, which is interacted with a binary indicator for each year t to obtain $BRDR_{ij,t}$. On the latter, a parameter β_t is estimated for each year t separately.

We will use the model in (1) to estimate it on the dataset of Baier, Yotov and Zylkin (2019). This dataset covers total bilateral trade of manufactures among 69 countries over the period 1986-2006, and it has several advantages for our purposes.[4] First, the dataset includes domestic/intra-national trade flows, which are needed for theory-consistent gravity estimations.[5] As demonstrated by Baier, Yotov and Zylkin (2019) the estimates of FTAs are affected by the inclusion of domestic trade flows, since the presence of the latter allow for capturing of trade diversion effects from domestic sales. Second, the time span of the dataset is relatively long, and it covers a period of intense globalization efforts with a number of new FTAs. Third, consistent with our focus, the dataset has already been used to analyze the impact of FTAs. Data on FTAs come from the NSF-Kellogg Database on Economic Integration Agreements of Jeff Bergstrand. A list of the FTAs that are used in the estimating sample as well as a list of the countries in the dataset appear in the Data Appendix. For further description of the data, its sources and construction we refer the reader to Baier, Yotov and Zylkin (2019).

In order to obtain estimates of the parameters $(\alpha, \alpha_s, \beta_k)$, we will make use of the dataset in two conceptually different ways. In one type of analysis, we will only use data from every τ-th year, where we will choose $\tau = \{5, 4\}$ to form in-

[4]For computational ease and given the main goal of their project to estimate the impact of FTAs, Baier, Yotov and Zylkin (2019) group the 17 countries in their sample that had not signed any agreements during the period of investigation into a 'Rest Of the World' (ROW) region. Treating these countries individually does not alter the main conclusions. A list of the countries in the estimating sample appears in the Data Appendix.

[5]Intra-national trade flows are constructed as the difference between the gross value of total production and total exports. The original international trade data come from the United Nations (UN) COMTRADE database, accessed via WITS. The data on total gross production come from the CEPII TradeProd database and the UNIDO IndStat database.

tervals. Hence, when $\tau = 5$, we will use only 20% of the years, when $\tau = 4$, we will use 25% of the years, etc.[6] In the other type of analysis, we will use data for all years, i.e., consecutive-year data. With the 5-year interval approach this means that we use data from only the years $\{1986, 1991, \ldots, 2001, 2006\}$ for estimating the parameters in the columns labeled "Interval", while we will estimate the parameters pertaining to the years of the interval but using data for all consecutive years $\{1986, 1987, ..., 2005, 2006\}$ in the columns labeled "Consecutive".

3 Estimation Results and Analysis

Our main findings are presented in Table 1. Following Cheng and Wall (2005) and Baier and Bergstrand (2007), our first specification is based on 5-year interval data. Specifically, we then use only data from the years 1986, 1991, 1996, 2001, and 2006. Several findings stand out from column (1). First, the positive and significant estimate of the contemporaneous effect of FTAs suggests that FTAs promote trade between their members (relatively) immediately, as expected. Second, the positive and significant estimate on FTA_{t-5} captures the phasing-in effects of FTAs, suggesting that FTAs need time to expand their full effect on trade between member countries. Third, the estimate on FTA_{t-10} is economically small and statistically insignificant, implying that FTAs have reached their full potential ten years after their entry into force. Fourth, the insignificant estimate on FTA_{t+5} is an indicator that there is a lack of anticipation and the FTA indicator passes the strict exogeneity

[6]Sometimes, data are not dropped but averaged (see for example Lendle et al., 2016). While averaging leads to smoother data, it still reduces the number of observations. We therefore stick with the comparison of the interval data with the full data.

Table 1: On the impact of FTAs on trade

	(1)	(2)	(3)	(4)	(5)	(6)
	5-year Lags		4-year Lags		1-year Lags	2-year Lags
	Interval	Consecutive	Interval	Consecutive	Consecutive	Consecutive
FTA_{t+5}	-0.021	-0.036			-0.083	
	(0.061)	(0.053)			$(0.043)^{+}$	
FTA_{t+4}			-0.038	-0.006	-0.022	-0.051
			(0.058)	(0.050)	(0.017)	(0.045)
FTA_{t+3}					0.070	
					$(0.021)^{**}$	
FTA_{t+2}					0.027	0.089
					(0.028)	$(0.035)^{*}$
FTA_{t+1}					0.060	
					$(0.015)^{**}$	
FTA_{t}	0.122	0.107	0.056	0.074	-0.047	-0.000
	$(0.064)^{+}$	$(0.049)^{*}$	(0.040)	$(0.042)^{+}$	$(0.018)^{*}$	(0.022)
FTA_{t-1}					0.034	
					$(0.020)^{+}$	
FTA_{t-2}					0.022	0.068
					(0.019)	$(0.022)^{**}$
FTA_{t-3}					0.063	
					$(0.031)^{*}$	
FTA_{t-4}			0.181	0.179	0.063	0.118
			$(0.045)^{**}$	$(0.030)^{**}$	$(0.018)^{**}$	$(0.026)^{**}$
FTA_{t-5}	0.180	0.182			0.044	
	$(0.040)^{**}$	$(0.024)^{**}$			$(0.009)^{**}$	
FTA_{t-6}					0.003	0.056
					(0.016)	$(0.015)^{**}$
FTA_{t-7}					0.071	
					$(0.029)^{*}$	
FTA_{t-8}			0.115	0.066	-0.005	0.026
			$(0.043)^{**}$	$(0.036)^{+}$	(0.014)	(0.027)
FTA_{t-9}					-0.014	
					(0.013)	
FTA_{t-10}	0.068	0.042			0.028	0.022
	(0.044)	(0.030)			$(0.017)^{+}$	(0.020)
Total FTA	0.301	0.289	0.238	0.253	0.358	0.331
	$(0.079)^{**}$	$(0.062)^{**}$	$(0.069)^{**}$	$(0.062)^{**}$	$(0.056)^{**}$	$(0.081)^{**}$
# Observations	14045	58989	16854	58989	58989	58989

Notes: This table reports estimates of the effects of FTAs on international trade. The dependent variable is always trade in levels and all estimates are obtained with the PPML estimator and exporter-time, importer-time, country-pair fixed effects, and time-varying border dummies. The estimates of all fixed effects are omitted for brevity. Column (1) reports estimates that are obtained with 5-year interval data and 5-year FTA lags and leads. Column (2) reproduces the results from column (1) but with a sample that uses all years. Columns (3) and (4) correspond to columns (1) and (2), but instead of using 5-year intervals and 5-year FTA lags and leads, they employ 4-year intervals and FTA lags and leads. Column (5) uses all years in the sample and 1-year FTA lags and leads. Finally, column (6) also employs the whole data but with 2-year FTA lags and leads. Standard errors are clustered by country pair. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

test, c.f. Baier and Bergstrand (2007). Finally, the total FTA effect that appears in the bottom panel of Table 1, which we obtain as the sum of the (statistically significant) parameters above it, i.e., the contemporaneous and the 5-year phasing-in FTA estimates, implies that, all else equal, the FTAs that entered into force during the period of investigation have led to an average increase of 35.2% (with a standard std.err. of 10.614) in bilateral trade between the FTA members relative to the non-members. The estimates in column (2) of Table 1 replicate the results from column (1), but using data for all years. A comparison between the results in columns (1) and (2) reveals that they are not statistically different from each other.

In columns (3) and (4), we conduct the same analysis as in columns (1) and (2) except that we use every fourth (rather than every fifth) year of data, namely ones from 1986, 1990, 1994, 1998, 2002, and 2006, and we use four-year intervals with leads and lags consistent with this. The main takeaway from the comparisons of the estimates in columns (1)-(2) and (3)-(4), respectively, is that estimations with four- and five-year interval data are only marginally different and the qualitative insights gained are identical. Moreover, estimations with interval data and those with data that are pooled over consecutive years deliver very similar estimates of the effects of FTAs.

The results in column (5) take advantage of the additional information in the consecutive-year sample to obtain a full set of year-on-year responses (including leads and lags) to the inception of FTAs. These estimates generate several new and interesting insights in relation to the results from the previous columns. First, we note that the estimates of the FTA anticipation effects for three years prior to the

agreement entering into force are positive and those of the 3- and the 1-year lead are also statistically significant. Hence, FTAs lead to an increase in trade between partners even before entering into force. We offer two explanations for this result. One is that once an agreement is announced, some firms start to adjust in anticipation of the implementation of the agreement (see Breinlich, 2014; Moser and Rose, 2014). In addition, it is possible that the potential member countries are already relaxing some administrative measures to reduce trade costs even before the agreement enters into force.[7] The pattern of anticipation effects that we document in column (5) are not (cannot be) captured with the interval samples in columns (1) and (3). Based on these estimates, we believe that it is important for econometric models to explicitly allow for anticipation effects of FTAs with data which are measured at a sufficiently fine granularity in the time dimension.

The second interesting result from the estimates in column (5) is that we obtain a negative estimate of the immediate/contemporaneous effect of FTAs (FTA_t). One explanation for this result might be that firms tend to have exaggerated expectations of the immediate effects of FTAs on average, and that the actual changes might take longer than expected due to granted phase-in effects of policy barriers, etc. This leads to our third observation, namely that the increase of the FTA effects is

[7] While we see scope for a rigorous theoretical investigation, this is beyond the scope of this paper. However, recent papers investigating the dynamics of trade flows, such as Eaton et al. (2011) or Anderson, Larch and Yotov (2020), may be fruitful starting points to build a theoretical framework able to capture the phases of FTAs. For example, in a dynamic framework, anticipation of the conclusion of FTAs in the future may lead to more consumption and trade today. If these anticipation effects work through general-equilibrium effects, they should be accounted for by our fixed effects (see Anderson, Larch and Yotov, 2020). But the anticipation of trade-cost changes may change the allocation of bilateral trade transaction in time. Additionally, sluggish adjustments of prices could potentially motivate lags of FTA effects.

the strongest between three ($t+3$ ($=FTA_{t-3}$)) and five years ($t+5$ ($=FTA_{t-5}$)) from their entry into force. The effects of FTAs during this period are all positive and statistically significant, increasing at first and then peaking in the middle and tapering off towards the end of that phase. The final result from column (5) is that the cumulative impact of FTAs in our sample reaches its full potential after about seven years ($t+7$ ($=FTA_{t-7}$)) from their implementation. This, in combination with the positive anticipation effects that we estimate imply that the dynamic-adjustment process takes about ten years until FTAs unfold their full effect.

Stimulated by the findings of Baier, Yotov and Zylkin (2019) who argue that the impact of FTAs vary significantly across agreements, we conclude our analysis with an experiment that evaluates the performance of interval vs. pooled data when we allow for heterogeneous FTA effects. To this end, we isolate the impact of two specific agreements: the FTA between Bulgaria and Turkey from 1998, and the FTA between Chile and Costa Rica from 2002. We chose these agreements because they are bilateral and because one of them (i.e., Bulgaria-Turkey) entered into force approximately in the middle of our sample, while the other one (i.e., Chile-Costa Rica) entered into force towards the end of the period of investigation.

Our findings are presented in Table 2, where, for comparison purposes, the first two columns reproduce the estimates with 5-year interval vs. pooled data from columns (1) and (2) of Table 1, respectively. Columns (3) and (4) of Table 2 report on the estimates of the impact of the FTA between Bulgaria and Turkey from 1998. To ease the interpretation, we isolate the FTA indicators for the Bulgaria-Turkey FTA from the ones referring to other FTAs. Thus, the estimates of the effects of the

Table 2: On the impact of FTAs on trade

	(1)	(2)	(3)	(4)	(5)	(6)
	ALL FTAs		BGR-TUR FTA		CHL-CRI FTA	
	Interval	Consecutive	Interval	Consecutive	Interval	Consecutive
FTA_{t+5}	-0.021	-0.036	-0.023	-0.038	-0.021	-0.036
	(0.061)	(0.053)	(0.061)	(0.053)	(0.061)	(0.053)
FTA_t	0.122	0.107	0.122	0.107	0.121	0.107
	$(0.064)^+$	$(0.049)^*$	$(0.064)^+$	$(0.049)^*$	$(0.064)^+$	$(0.049)^*$
FTA_{t-5}	0.180	0.182	0.179	0.181	0.180	0.182
	$(0.040)^{**}$	$(0.024)^{**}$	$(0.040)^{**}$	$(0.024)^{**}$	$(0.040)^{**}$	$(0.024)^{**}$
FTA_{t-10}	0.068	0.042	0.069	0.043	0.068	0.042
	(0.044)	(0.030)	(0.045)	(0.030)	(0.044)	(0.030)
BGR_TUR_{t+5}			1.150	1.757		
			$(0.039)^{**}$	$(0.049)^{**}$		
BGR_TUR_t			0.211	0.143		
			$(0.075)^{**}$	$(0.044)^{**}$		
BGR_TUR_{t-5}			0.472	0.496		
			$(0.043)^{**}$	$(0.058)^{**}$		
CHL_CRI_{t+5}					-0.123	0.126
					(0.078)	$(0.072)^+$
CHL_CRI_t					0.475	0.201
					$(0.077)^{**}$	$(0.057)^{**}$
# Observations	14045	58989	14045	58989	14045	58989

Notes: This table reports estimates of the effects of FTAs on international trade. The dependent variable is always trade in levels and all estimates are obtained with the PPML estimator and exporter-time, importer-time, country-pair fixed effects, and time-varying border dummies. The estimates of all fixed effects are omitted for brevity. For comparison purposes, columns (1) and (2) reproduce the estimates from columns (1) and (2) of Table 1. Columns (3) and (4) isolate the individual impact of the 1998 FTA between Bulgaria and Turkey. Similarly, columns (5) and (6) isolate the individual impact of the 2002 FTA between Chile and Costa Rica. Standard errors are clustered by country pair. $^+$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Bulgaria-Turkey FTA can be interpreted in levels. Before we analyze the results, we note that we cannot obtain an estimate on the 10-year lag, BGR_TUR_{t-10}, because it is outside the span of our sample. A comparison between the estimates in columns (3) and (4) reveals the following. First, the lead estimate with the pooled data is significantly larger. Second, the estimate of the contemporaneous FTA effect obtained with the consecutive-year data in column (4) is significantly smaller. Finally, the estimates of the 5-year phasing-in effects are very similar in columns (3) and

(4). In sum, the results for the Bulgaria-Turkey FTA reveal significant differences depending on whether the sample is with intervals or with consecutive years.

Columns (5) and (6) of Table 2 isolate the impact of the FTA between Chile and Costa Rica from 2002. Due to the fact that this agreement was formed toward the end of our sample period, we cannot obtain estimates for the 5- and the 10-year lags. Two main findings stand out from a comparison between the estimates in columns (5) and (6). First, we see that the estimate on the lead CHL_CRI_{t+5} is not statistically significant (and in fact negative) with the interval sample, while the estimate with the consecutive year sample is positive and at least marginally statistically significant. Second, we see that the estimate of the contemporaneous effects of the Chile-Costa Rica FTA that is obtained with the interval sample is more than twice larger as compared to the estimate from the sample with pooled data. Both of these results are consistent with our findings for the Bulgaria-Turkey FTA.

Based on the results in Table 2 we conclude that the agreement-specific estimates of the effects of FTAs can be very different when obtained with interval vs. consecutive-year data. This reinforces our main argument that estimates that are obtained with annual/consecutive-year data, i.e., the full sample, should be preferred over interval-data estimates, which may be biased. While, in principle, the bias in the estimates with interval data can go in either direction, our results reveal some notable and interesting patterns that we try to summarize and generalize in the next section.

4 Discussion and Implications

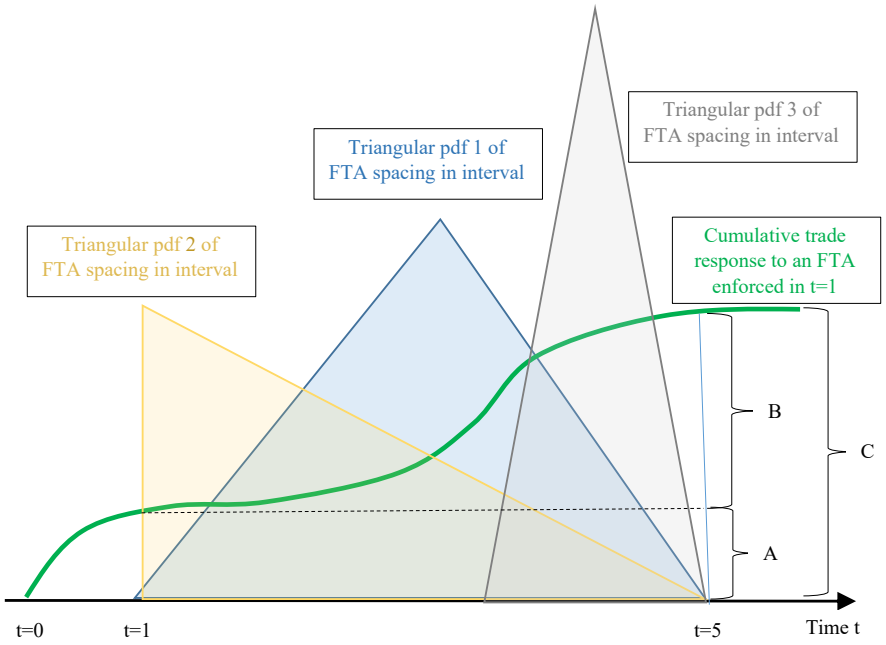
A comparison of the cumulative effects at the bottom of Table 1 indicates that they are not starkly statistically different from each other, but the point estimates in columns (1)-(4) differ in magnitude from the ones in column (5) in a way that we try to summarize and generalize in Figure 1. In the figure, we draw the dynamic response locus of bilateral trade for a hypothetical FTA that came into force in year $t = 1$. In the illustration, we assume that a researcher "bins" the data in (non-overlapping) 5-year intervals between which the parameters are identified. Of those intervals, we focus on the one between $t = 1$ and $t = 5$. We display three alternative hypothetical density functions of FTA enforcements during this interval. With a true dynamic response as displayed by the green locus, note that FTAs behind each one of the three density functions would have their own respective response, and the density functions would suggest how to weigh (average) them.

The figure illustrates that the problem with intervals and unequally spaced FTAs is that they cannot possibly do justice to the adjustment process, because the response is not measured relative to the true enforcement time but to the arbitrarily placed time window.[8] With the example at hand (if all FTAs in the data would materialize within the chosen window), the parameter on an FTA indicator would be a biased estimate of the short-run (within-first-year) and long-run (accumulated-process) response.[9] The reason for the biases are the following. The event-time

[8]The aggregation of data in bracketed time intervals is a well-studied problem in the macro-econometrics literature and some of the problems and biases we mention here are the same as the ones the respective literature addresses (see Hassler, 2013).

[9]Note that the event densities could be used to generate a fractional variable from a binary FTA indicator, which would reflect the fraction of years the average FTA was in place during the

Figure 1: Spacing of FTA events over an arbitrary time window of 5 years



Note: The green locus of this figure displays a hypothetical cumulative effect of an FTA enforced in t=1 on bilateral trade. The blue, yellow, and grey triangles display hypothetical event densities of FTA enforcements across country pairs in the data. In the portrayed situation, a 5-year time-interval data approach which uses an interval from t=1 to t=5 would bias results due to mixing density-weighted delay-, anticipation-, and during-window effects. A indicates the magnitude of the anticipation effect of an FTA implemented at t=1. B indicates the accumulated associated effect between t=1 and t=5. The cumulative effect at t=5 is A+B. The long-run effect is C>A+B. A bias of the effect of FTAs may emerge from a mix of the enforcement of FTAs in time between the interval endpoints.

pattern (associated with the densities) in the figure together with the effect schedule entails that the effects estimated from the window relative to before are mixes of density-weighted delay-, anticipation-, and during-window effects. Note that depending on when an FTA is "born", the green curve starts one period ahead of that. Hence, we obtain a density-weighted average of green curves that are horizontally

window. Alternatively, one could use a binary indicator which is unity whenever an FTA was in place any time during the interval. Clearly, the former is preferable for the latter, but it it only mattrers for the magnitude but not the direction of the biases in the example.

(in t) shifted. That means that the interval estimator may lead to biased short-run and long-run effects. One source of the bias is that some anticipation happens before the window and delay effects happen after it. Note that there are even anticipation effects during the window (for late-coming FTAs), and there the cumulated delay effects will be big. Overall, the figure illustrates that it would be necessary to measure the response intensity relative to the true inception time of FTAs rather than anchored in a fixed way on the time array. In other words, the misalignment and the variation of the phases of the adjustment process to an FTA inception together relative to the spacing of the interval boundaries in time are a source of bias of the response estimates.

To demonstrate this point with our data, Table 3 illustrates the distribution of new FTA memberships across the years 1986-2006 and country pairs in the data. In that table, we provide the specific years, the number of new country pairs in FTAs in a year, and two columns pertaining to the distribution of new FTA memberships within a 5-year interval approach by way of an example. The table demonstrates that during the study period FTA memberships were distributed quite unevenly (in other words, they were unequally spaced in time). The 5-year interval approach starting in 1986 leads to a situation where there is a concentration of new memberships in the center in some intervals (e.g., in 1986-1990), while there is one towards the end in other intervals (e.g., in 1991-1995). The numbers in the last column are interval-length averaged durations of new memberships within 5-year intervals. A lower number suggests that new memberships are skewed towards the end (with a theoretical minimum value of 0.2 if all FTAs within the 5-year interval would enter

Table 3: Distribution of new FTA memberships within 5-year intervals

(1) Year	(2) Number of FTAs	(3) Share of FTAs	(4) Interval-length-averaged Durations
1986	0	0.00	
1987	0	0.00	
1988	26	0.93	
1989	2	0.07	
1990	0	0.00	0.59
1991	0	0.00	
1992	12	0.05	
1993	68	0.28	
1994	48	0.20	
1995	114	0.47	0.38
1996	42	0.17	
1997	8	0.03	
1998	72	0.28	
1999	2	0.01	
2000	130	0.51	0.47
2001	2	0.01	
2002	6	0.03	
2003	38	0.18	
2004	142	0.68	
2005	20	0.10	0.43
2006	10	1.00	

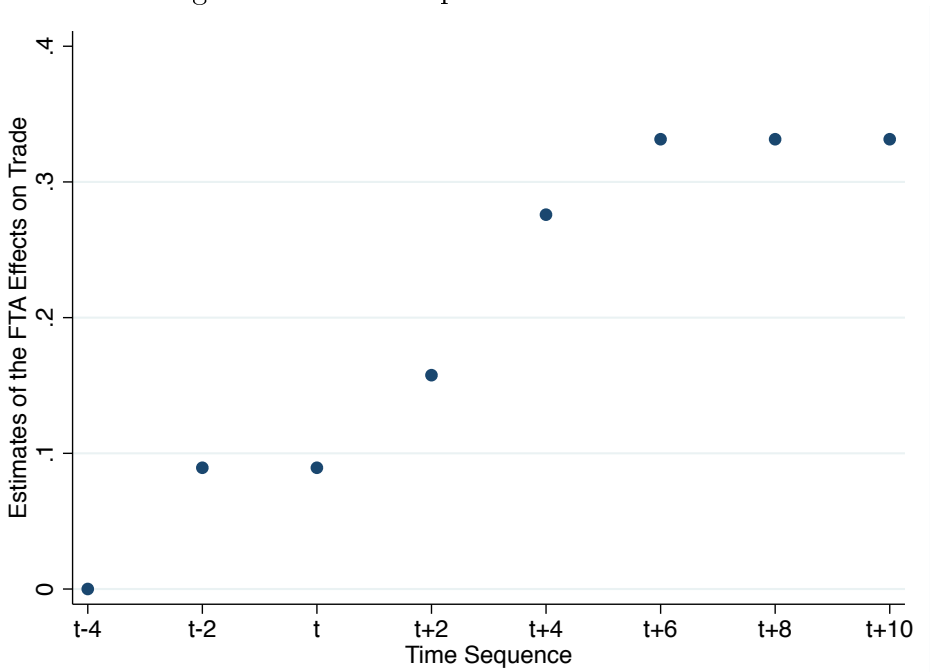
Notes: This table reports the specific years in column (1), the number of new-FTAs country pairs in a year in column (2), the share of FTAs concluded in a specific year within 5-year intervals (distinguished by lines) of all FTAs concluded in the 5-year interval in column (3), and the interval-length averaged durations of new memberships within 5-year intervals in column (4). We normalized the latter interval to unity, so that the number in the last column is the fraction of years the average new FTA in an interval existed.

into force in the last year of the interval), while a higher one suggests that they are skewed towards the beginning of an interval (with a theoretical maximum value of 1 if all FTAs within the 5-year interval would enter into force in the first year of the interval). With underlying dynamics of adjustment of outcome to new memberships as in Figure 1, this means that the parameters measured on "contemporaneous" FTA measured only at interval boundaries $\{1986, 1991, \ldots\}$ are prone to a bias which comes from the underlying aggregation of dynamic patterns from within intervals. In any case, the time-interval aggregation hinders the identification of the form of the response process of trade flows to FTAs, which is reflected in the estimates in Table 1.

Towards checking the robustness of the annual-data-based analysis in column (5), we conduct the same analysis based on consecutive-year data but after constraining the FTA estimates to be common biannually. This may be viewed as a hybrid approach between the ones in columns (1)-(4) and the one in column (5). The corresponding results are summarized in column (6). Of course, the results in column (6) broadly confirm the pattern of the evolution of the dynamic responses in column (5). They miss out on some of the details of the process by design, a problem which is aggravated by using bigger intervals. But the specification in column (6) reveals seven distinct phases of the long-run impact of FTAs on international trade in a way which is easier to grasp than in column (5). We visualize these phases in Figure 2 by plotting the significant estimates from column (6) (again setting non-significant ones to zero), and we discuss each phase in turn next.

- *The 'Pre-FTA Phase'.* According to our estimates, this phase covers the period

Figure 2: On the impact of FTAs on trade



Note: This figure visualizes the estimates from column (6) of Table 1. Specifically, the estimates in the figure are constructed by adding the statistically significant estimates from column (6), and plotting non-significant ones as zeros. Thus, for example, by construction the 't+6' (=FTA_{t-6}), '$t+8$' (=FTA_{t-8}), and '$t+10$' (=FTA_{t-10}) points in the figure represent the total average FTA effect for the FTA members in our sample.

up to four years prior to the implementation of the agreements, and there are no important FTA effects on trade during this period. For proper timing of the duration of this phase, our practical estimation recommendations are (i) to use country-pair fixed effects as in Baier and Bergstrand (2007), and (ii) to eventually allow for sufficiently many lead effects of FTAs.

- *The 'Anticipation Phase'.* According to our estimates, this phase covers up to three years before the entry into force of an FTA, and during this period we obtain positive estimates of the impact of FTAs on trade. As noted earlier,

we attribute such positive FTA effects to firm adjustment in anticipation of the agreement and/or to leading changes in trade costs in preparation of the agreement between the member countries. Our estimation recommendation in relation to this phase are to definitely allow for lead effects of FTAs during the years immediately preceding their implementation. In terms of timing this phase, intuitively, we expect that such lead effects may start showing up when an agreement is announced and, more likely, between the period of signing an agreement and its entry into force (see Breinlich, 2014; Moser and Rose, 2014).

- *The 'Introduction Phase'.* This phase covers the year of entry into force and possibly the following year. Our estimates reveal no statistically significant cumulative impact of FTAs on trade during this phase, and our explanation for this results is that this is a period of adjustment to the new trade rules and conditions. Moreover, most FTAs come with a phase-in period where policy barriers are slowly reduced at the beginning. Finally, some firms may have had exaggerated expectations about the immediate consequences of the inception of an FTA or underestimated the competition of firms in the markets they are integrating with. From an economic and policy perspective, the underlying adjustment processes that take place during this phase are important and, therefore, we believe that this phase should be treated separately.

- *The 'Adjustment Phase'.* The fourth phase covers the period between one and two years after the FTA's entry into force and, during this phase, we obtain small, but positive and statistically significant estimates of the impact of FTAs on trade. The natural explanation for such positive estimates is that the impact

of the FTAs is starting to kick in after the introduction phase and the continued reductions in policy barriers are gaining bite. Our estimates suggest an intuitive and statistically different impact of FTAs during this period. Thus, we believe that it should be accounted for separately.

- *The 'High Growth Phase'.* This phase takes place between three and six years after the entry into force of FTAs and, according to our estimates, this is the period when the FTA impact on trade flows among FTA members displays its largest increments. The intuition is that after the initial adjustment, the phased-in policy changes, and with some added experience already, firms are now able to take full advantage of the new trade opportunities and conditions. We also note that the impact of FTAs in this phase is stronger than in the 'Anticipation Phase'. The natural explanation is that there is no longer any uncertainty about the time of entry into force of the FTA and the specifics of its design, and the trade costs between the member countries have been lowered to a more or less full extent on average.

- *The 'Slow Growth Phase'.* This phase takes place between seven and eight years after the FTA's entry into force and, according to our estimates, there is still an increase in the impact of FTAs, but the magnitude of the increments is declining relative to the previous phase.

- *The 'Maturity Phase'.* According to our estimates, the impact of the FTAs in our sample has reached its full effect after about eight years from their implementation or, as noted earlier, about 10-11 years after the initial (anticipation)

impact of FTAs on trade among member countries. We believe that in order to obtain proper estimates of the impact of FTAs in the 'Maturity Phase', one must use country-pair fixed effects in combination with pooled data to ensure a proper identification of its timing. In combination with our findings regarding anticipation effects, these results imply that it takes about 10-11 years until the FTAs unfold their full potential. This is consistent with estimates from the existing literature, e.g., Baier and Bergstrand (2007). Importantly, however, our analysis reveals details on the phases of adjustment processes to FTA effects on trade which are beyond the reach of estimates that do not use panel data with a sufficiently high frequency.

5 Conclusion

Using time-interval data of bilateral trade flows and trade-policy variables has become a widely used practice, in particular, when estimating the direct effects of free-trade agreements (FTAs) on bilateral trade flows. Such direct effects are important structural parameters that are used to quantify multi-country general equilibrium models of open economies. By using time-interval rather than annual data, it is argued that adjustments and short-run fluctuations are taken into account. We challenge this practice.

One problem with interval data is that they can lead to biases of the total (accumulated) direct effects of FTAs or other trade-policy variables. Moreover, they are prone to misrepresent – in particular, with longer intervals – the pattern of the

response function. Using annual and biannual instead of longer-interval data, we are able to identify seven phases of FTA effects on trade flows during the dynamic adjustment process for the average country pair. Distinguishing these phases is only possible when using the information of trade flows and FTAs at a sufficiently high frequency. Hence, we argue for efficiency and identification reasons to use all data available rather than to use intervals.

While we provide empirical evidence for seven different phases of FTA effects on trade flows, we think that it would be fruitful to inform theoretical models based on these stylized facts. Such theorizing might be the basis of richer quantitative dynamic models which are currently not available.

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Data Appendix

Table 4: Included Countries

Main sample *(52 countries/regions)*: Argentina, Australia, Austria, Bulgaria, Belgium-Luxembourg, Bolivia, Brazil, Canada, Switzerland, Chile, China, Colombia, Costa Rica, Cyprus, Germany, Denmark, Ecuador, Egypt, Spain, Finland, France, United Kingdom, Greece, Hungary, Indonesia, Ireland, Iceland, Israel, Italy, Jordan, Japan, South Korea, Kuwait, Morocco, Mexico, Malta, Myanmar, Malaysia, Netherlands, Norway, Philippines, Poland, Portugal, Qatar, Romania, Singapore, Sweden, Thailand, Tunisia, Turkey, Uruguay, United States
"Rest of World" *(17 countries/regions)*: Cameroon, Hong Kong, India, Iran, Kenya, Sri Lanka, Macau, Mauritius, Malawi, Niger, Nigeria, Nepal, Panama, Senegal, Trinidad & Tobago, Tanzania, South Africa

Table 5: Included Agreements

Multilateral Trade Blocs		
Agreement	Year	Member Countries
ASEAN*	2000	Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand
Agadir	2006	Egypt, Jordan, Morocco, Tunisia
Andean Community†	1993	Bolivia, Colombia, Ecuador
CEFTA	1993	Poland (1993-2004), Hungary (1993-2004), Romania (1997-2004), Bulgaria (1998-2004)
EFTA	1960	Norway, Switzerland, Iceland (1970), Portugal (1960-1986), Austria (1960-1995), Sweden (1960-1995) Finland (1986-1995).
EU†	1958	Belgium-Luxembourg, France, Italy, Germany, Netherlands, Denmark (1973), Ireland (1973), United Kingdom (1973), Greece (1981), Portugal (1986), Spain (1986), Austria (1995), Finland (1995), Sweden (1995), Cyprus (2004), Malta (2004), Hungary (2004), Poland (2004)
Mercosur*†	1995	Argentina, Brazil, Uruguay
NAFTA	1994	Canada, Mexico, U.S.
Pan Arab Free Trade Area	1998	Egypt, Kuwait, Jordan, Morocco, Qatar, Tunisia

EFTA's outside agreements: Turkey (1992), Bulgaria (1993), Hungary (1993), Israel (1993), Poland (1993), Romania (1993), Mexico (2000), Morocco (2000), Singapore (2003)

EU's outside agreements: EFTA (1973), Cyprus (1988), Hungary (1994), Poland (1994), Bulgaria (1995), Romania (1995), Turkey (1996)†, Tunisia (1998), Israel (2000), Mexico (2000), Morocco (2000),Chile (2003), Egypt (2004)

Other agreements: Australia-Singapore (2003), Australia-Thailand (2005), Australia-U.S. (2005), Bulgaria-Israel (2002), Bulgaria-Turkey (1998), Canada-Chile (1997), , Canada-Costa Rica (2003), Canada-Israel (1997), Canada-U.S. (1989), Chile-China (2006), Chile-Costa Rica (2002), Chile-Mexico (1999), Chile-Singapore (2006), Chile-South Korea (2004), Chile-U.S. (2004), Colombia-Mexico (1995), Costa Rica-Mexico (1995), Egypt-Turkey (2006), Hungary-Israel (1998), Hungary-Turkey (1998), Israel-Mexico (2000), Israel-Poland (1998), Israel-Romania (2001), Israel-Turkey (2001), Japan-Mexico (2005), Jordan-U.S. (2002), Mercosur-Andean (2005), Mercosur-Bolivia (1996), Mercosur-Chile (1996), Mexico-Uruguay (2005), Morocco-U.S. (2006), Poland-Turkey (2000), Romania-Turkey (1998), Singapore-U.S. (2004), Tunisia-Turkey (2006)

*For these two blocs, we follow the NSF-Kellogg Database in using, respectively, the date at which ASEAN "moved toward" becoming a free trade area and the date at which Mercosur became a customs union.

†Denotes a deeper level of agreement (e.g., a customs union).