Assessing the Impact of the Trade Facilitation Agreement on Agri-Food Global Value Chain Integration*

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Abstract

This paper examines the impact of the Trade Facilitation Agreement (TFA) on the integration of agri-food global value chains (GVC). While the TFA aims to reduce trade costs and enhance cross-border trade, our findings indicate that higher levels of TFA implementation are linked to decreased agri-food GVC participation. This suggests that the marginal costs of implementing trade facilitation measures may outweigh the benefits. Notably, only three out of twelve TFA articles positively impact GVC flows, highlighting significant heterogeneity among provisions. Moreover, Lasso regression analysis suggests that the observed positive effects may be confounded by countries' joint WTO membership. These results underscore the complexity of implementing trade facilitation measures and provide crucial insights for policymakers for future trade negotiations.

Keywords: Agri-food global value chains, World Trade Organization, Trade Facilitation Agreement, structural gravity model, event studies, Lasso machine learning

JEL codes: F13, Q17

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1. Introduction

In 2017, the Trade Facilitation Agreement (TFA) brokered by the World Trade Organization (WTO) entered into force, with initial estimates suggesting annual trade gains between $750 billion and $1 trillion upon full implementation (WTO, 2015). However, these early ex-ante estimates overlooked the potential implementation costs associated with each TFA measure. Section I of the TFA comprises twelve articles, each containing various measures to reduce trade costs, with some measures entailing higher implementation costs than others.[1] This is particularly relevant to agri-food GVCs, where intermediate goods often traverse multiple borders, sometimes re-entering the same country (Balié et al. 2019; Greenville, Kawasaki and Beaujeu 2017; OECD 2018). As a result, each TFA provision may have varying effects on GVC flows. The TFA's *à la carte* approach considers the complexities of each article and allows developing countries to select their timeline for implementing the agreement based on their needs and required capacity-building assistance.[2] For each measure, these countries must notify their intended implementation dates. This approach enables developing countries to implement less complicated provisions while postponing the more challenging ones for later (Hillberry and Zurita 2022).

A growing body of literature analyzes the TFA and the impacts of trade facilitation on trade and welfare. Hillberry and Zurita (2022) conduct the first formal statistical analysis of cross-country commitment behavior in the TFA. They use data from the Trade Facilitation Agreement Database (TFAD) and find that the number of provisions that countries pledge to implement within one year after the agreement's entry into force is related to per capita income.[3] Beverelli et al. (2023) also use data from the TFAD to estimate the impact of joint commitments under the agreement between country pairs on bilateral trade flows and welfare. They find that TFA implementation has increased global agricultural exports by 5%. However, they do not consider heterogeneous effects across TFA

[1] The International Trade Centre (2020) provides a detailed explanation of the scope of every article and sub-article in the TFA, along with their estimated implementation times, which range from one to five years.

[2] Developing countries may request financial and technical assistance to aid their TFA implementation efforts. An additional flexibility is the ability to adjust some implementation dates after they have been formally notified. More details are provided in the Background section.

[3] The TFAD is maintained by the WTO and is publicly available from `https://www.tfadatabase.org/en`.

articles or the number of TFA measures implemented. Other studies examine the effectiveness of trade facilitation policies on countries' trade flows using the Trade Facilitation Indicators (TFI) developed by the Organization for Economic Cooperation and Development (OECD).[4] The TFI construction uses publicly available data and questionnaires about users' insights to measure trade facilitation efforts in each country. Nonetheless, one shortcoming of the TFIs is that they do not record countries' actual notified TFA commitments.

We investigate the implications of the share of common TFA measures *notified* implemented between country pairs on agri-food GVC participation. We achieve this by estimating a three-way structural gravity model using annual data from the 2023 Eora global supply chain database for 188 countries between 2000 and 2021. GVC participation is measured as the value of imported inputs used in a country's exported goods, known as *backward participation*, or the value of domestic production used in the exports of foreign countries, referred to as *forward participation*. The number of TFA commitments countries have implemented in common is measured using TFAD data. Our regression results imply that full TFA implementation could be reached by 2034. In addition, our primary regression analysis suggests that when the share of common TFA measures implemented is less than half, their relationship with GVC participation is insignificant. Higher levels of common implementation are associated with lower values of GVC participation. We also find that only three of the twelve TFA articles are associated with higher GVC flows. A Lasso regression analysis suggests that any positive relationship between TFA implementation and GVCs may be confounded with countries' WTO membership. Event studies reveal that once countries begin having common TFA commitments implemented, there is a negative effect on agriculture GVC flows.

Our paper contributes to three strains of the literature on GVC integration and the impact of multilateral economic agreements. First, we answer the question of whether trade facilitation increases GVC participation in the agri-food sector. Reducing trade costs not only aids countries in their integration into GVCs but also empowers them to transition toward higher-value economic activities

[4] Examples of these works include Beverelli, Neumueller and Teh (2015); Fontagné, Orefice and Piermartini (2020); Hillberry and Zhang (2018); Moïsé and Sorescu (2013).

(Shepherd 2016). Our work is closely related to Beverelli et al. (2023), who analyze the impact of common TFA implementation on bilateral trade flows. They estimate a general equilibrium model, where common agreement implementation reduces non-tariff barriers. Our contribution to the literature involves considering the shares of full TFA implementation and conducting a separate analysis of implementation by individual articles. Each article varies in scope and implementation complexity, with some requiring only minor procedural adjustments while others demanding enhanced local inter-agency cooperation in advanced IT platforms. Given the flexibility of the TFA, developing countries may initially implement the measures with the lowest implementation costs, but these costs increase as they work to implement the remaining measures. Moreover, we contribute to the literature by disaggregating trade flows into GVC participation and examining agri-food GVCs in particular, which hold significance for developing countries due to their comparative advantage in agriculture and perishable goods (USAID 2019).

Another contribution of ours is the use of the gravity framework to study the effects of trade facilitation on GVC flows, expanding on the earlier work by Masood and Martínez-Zarzoso (2023). Their trade facilitation measures are sourced from the UN Global Survey on Digital and Sustainable Trade Facilitation, which encompasses TFA measures and those from other agreements and verifies whether these measures are implemented. They find positive effects of trade facilitation on bilateral trade. In contrast, we focus on the measures explicitly outlined in the TFA and those formally notified as implemented. The act of informing implementation makes these commitments binding. We find that the only TFA articles associated with higher values of GVC participation are *Article 6. Disciplines on Fees and Charges*, *Article 7. Release and Clearance of Goods*, and *Article 9. Movement of Goods Under Customs Control*. Implementing all other articles has a neutral or negative relationship with GVC flows. However, a Lasso variable selection method indicates that the implementation levels of Articles 6, 7, and 9 may be collinear with joint WTO membership. This suggests that any positive effects on bilateral GVC flows attributed to the TFA might stem from joint WTO membership of importers and exporters rather than the agreement itself.

A final contribution of our paper is that we track the number of implemented measures from the agreement's entry into force in 2017 to 2021. Hillberry and Zurita (2022) study how countries make the so-called Type A TFA commitments, which are commitments to implement measures

within one year of the agreement's entry into force. They study which trade facilitation policy areas are those where countries make the most Type A commitments. We study which areas are progressing more slowly in TFA implementation, considering measures' notified implementation dates, regardless of commitment types. Among these areas, some have a more pronounced impact on integrating developing countries into GVCs (Moïsé and Sorescu 2013; USAID 2019). The slowest progress in implementation is observed in measures related to *border agency cooperation* and *single window*. Regarding agricultural GVC integration, border agency cooperation is critical due to the application of sanitary and phytosanitary (SPS) measures and inspections to agri-food products (USAID 2019). Similarly, a single window can help reduce import and export document preparation time, which affects time-sensitive agricultural exports.[5] Hillberry and Zurita (2022) also study whether the number of Type A commitments made is related to various country characteristics, such as income, population size, and per capita aid for trade received. We explore whether country characteristics affect how fast countries have notified measures as implemented between 2017 and 2021. A regression analysis indicates that countries implement one additional measure annually for each additional dollar of per capita aid for trade. Moreover, we estimate a tentative number of years until WTO country members reach full TFA implementation. Our estimates suggest that full TFA implementation could be reached by 2034.

2. TFA Background

Trade Facilitation refers to the simplification, modernization, and harmonization of export and import processes (WTO, 2023*a*). In line with this, the TFA outlines a set of provisions to expedite the movement, release, and clearance of goods, including those in transit. The agreement's measures are detailed in twelve articles, which are divided into 238 provisions in the TFAD, with each provision representing roughly one paragraph of the agreement. These provisions cover 36 functional policy areas to reduce trade costs associated with the cross-border movement of goods. Some measures include best practices on discipline and fee transparency, customs regulations and formalities, border agency cooperation, and information availability.

[5] Djankov, Freund and Pham (2010) find that that a 10% increase in export time reduces time-sensitive agricultural exports by 3.5%.

The TFA is the first agreement in WTO history with an *à la carte* structure, in the sense that it allows developing countries to choose their implementation timeline based on their own perceived readiness (Hillberry and Zurita, 2022; WTO 2014). Developed countries are assumed to have implemented all provisions upon ratification of the agreement. On the other hand, developing countries have a differentiated treatment. Upon ratification of the agreement, they must classify TFA provisions into commitment types A, B, or C (WTO, 2023*b*). Type A commitments are binding and mandate implementation within one year of the agreement's entry into force. Type B commitments allow for a transitional period before implementation, and Type C commitments require more time, technical assistance, and capacity building (TACB). Countries may request additional time for Type B and C commitments and shift measures between these categories. However, it is not possible to retroactively shift a Type A commitment to Type B or C.

Developing countries must also notify an intended date on which they commit to implement each TFA provision. Countries first notify an *indicative implementation date*, which is an initial estimate of when a particular measure will be implemented (WTO, 2023*a*). Afterward, countries notify *definitive implementation dates*, which can be modified given appropriate reasons.[6] For example, recent requests to delay implementation include as a reason the COVID-19 pandemic and difficulties securing implementation assistance funds (WTO 2023*b*).

Concerns may arise regarding alignment between notified implementation dates and actual implementation. However, country members are incentivized to provide the most approximate dates for implementing TFA measures as the agreement obligations are subject to the WTO's Dispute Settle Mechanism. Article 20 in Section II of the TFA allows for grace periods for countries in the application of the *Understanding on Rules and Procedures Governing the Settlement of Disputes*. The grace period ranges from 2 to 8 years, depending on commitment types and the development level of each country member. For instance, the grace period for Type A commitments expired on February 22, 2019, while the grace period for Type B and C commitments is scheduled to expire on February 22, 2025. These deadlines incentivize developing country members to comply with their notified timeframe and seek assistance if needed.

[6] More details on notification requirements are available in the Frequently Asked Questions section of WTO (2023*b*).

In general, the *à la carte* approach empowers signatory countries to prioritize which provisions to implement first and request TACB according to their specific needs. Assistance is based on each member's implementation costs and challenges and may be requested from various entities, including the WTO, developed WTO members, the Organization for Economic Co-operation and Development (OECD), the World Bank, the World Customs Organization, and the United Nations Conference on Trade and Development (UNCTAD). The most frequent development partner is the World Bank, with 47 projects (WTO, 2023*b*). TACB covers a range of areas, including human resource training and support in information and communication technologies.[7]

3. Data

3.1 TFA Measures Notified as Implemented

Notified implementation dates for all TFA measures are obtained from the TFAD, which offers a comprehensive *article breakdown* of each developing country member's commitments.[8] There are a total of 238 measures, which are typically a paragraph of the Agreement. We count the number of measures notified as implemented every year after the agreement entered into force.[9] Our draw of article breakdowns was conducted on February 16, 2023, covering 121 developing countries. In addition, we include 40 developed WTO member countries with full TFA implementation and two developing WTO member countries with no measures implemented.[10] In the end, we have a panel dataset comprising 163 countries observed between 2017 and 2021.

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[7] To assist developing countries in TFA implementation, the WTO created the Trade Facilitation Agreement Facility (TFAF), which supports the assessment of countries' specific needs and identifies potential development partners to address those needs. A full list of TFAF supporting activities is available in WTO (2023*a*).

[8] Developed countries are presumed to have fully implemented the TFA upon its entry into force in 2017. Thus, the article breakdown is not provided for these countries.

[9] The TFA entered into force on February 22, 2017. For every subsequent year, $t \geq 2017$, we record a measure as implemented if the definitive implementation date is on or before February 22 of that year. Provisions without definitive implementation dates are considered as not implemented, even if they have a *tentative* implementation date. The TFAD does not track actual implementation, so our analysis is based on notified implementation.

[10] Developed countries are countries in the European Union, the USA, Canada, Australia, New Zealand, the United Kingdom, and Russia. The two developing countries with no implemented measures are Venezuela and Yemen. The European Union (EU) is considered an individual WTO member in the TFAD, but it is excluded as a member in our analysis. Instead, we consider each EU member separately.

Panel A of Appendix Table A.1 presents summary statistics of the annual number of measures reported as implemented. Upon the TFA's entry into force in 2017, the average number of TFA measures notified as implemented was 136.65, with a standard deviation of 97.22.[11] By 2021, the average increased to 165.23, and the standard deviation reduced to 79.60. This suggests a steady increase in countries' annual number of implemented measures. As countries move closer to full implementation, variability reduces. However, there is still considerable variability to exploit in our analyses. To estimate the pace of implementation, we calculate the number of measures a country needs to achieve full compliance, which we refer to as the *gap to full implementation*. For example, if a country has 200 measures notified as implemented, its gap is 38.

For the gravity analysis, we calculate the annual share of common full TFA implementation by every country pair (importer and exporter). This share is the number of identical measures notified as implemented by both countries, divided by the total number of measures in the TFA (238). It takes a value from 0 to 1, where 0 means that the importer and exporter have no common measures implemented, and 1 means full implementation by the importer and the exporter. To account for heterogeneity across measures, we calculate the share of common implementation at the article level. Each article of the 12 articles has a distinct number of measures. For example, *Article 1* has 22 measures, so its share is based on these 22 provisions.

3.2 Country Characteristics

We examine the relationship between the pace of implementation and various country characteristics. The country dimensions we choose are a subset of those used in (Hillberry and Zurita 2022). We aim to explore whether the pace of countries' measure implementation is conditional on country-specific characteristics. These variables are treated as stock variables, and unless otherwise specified, they correspond to values in 2016.[12] This allows us to capture the impact of country characteristics at the beginning of the agreement's entry into force. Panel B of Appendix Table A.1 presents descriptive statistics of the country characteristics for the 163 WTO member countries.

[11] The average includes the full implementation by developed countries. When the TFA entered into force, some developing countries reported already having some measures in place.

[12] Most countries have data available up to the year 2016.

The Dynamic Gravity Dataset (DGD) by Gurevich and Herman (2018) is our data source for per capita GDP, population, and indicators for landlocked and island status.[13] We use per capita GDP (GDP_{pc}) to explore if income affects countries' pace of implementation. GDP_{pc} is reported in current U.S. dollars ($) as technology and expertise imports may be necessary to successfully implement trade facilitation measures.[14] We also include population in our analysis since countries with larger populations may have increased access to trained personnel to support TFA implementation.[15] Moreover, countries with larger populations may have a greater demand for imports, potentially serving as an incentive for faster TFA implementation. Average GDP_{pc} is $15.10 thousand, and its standard deviation is $22.27, while the mean population is 42.68 million with a standard deviation of 153.96. This indicates substantial variability in income and population size.

Landlocked and island country indicators are included as dummy variables. Countries with these geographical characteristics face different sets of challenges for trade logistics, which may slow down the TFA implementation. However, the case could be such that landlocked or island countries implement TFA measures faster to overcome their logistics difficulties. In our sample, 20% of the countries are landlocked, and 19% are islands.

We incorporate the total amount of international aid that developing countries received for trade facilitation purposes, based on data from the OECD (2023) international development statistics database.[16] We sum aid flows from 2016 to the last year available, 2021, and divide by countries' populations to create a measure of per capita aid for trade (AFT_{pc}). We focus on this period because it covers the time after the agreement went into effect. Aid for trade could potentially increase a country's ability to implement TFA measures faster. This variable also accounts for the role of international support in the pace of implementation. Countries received an average $1.63

[13] The DGD is publicly available from https://www.usitc.gov/data/gravity/dgd.htm.

[14] GDP for Venezuela and Yemen is not available in the DGD and is obtained from the IMF (2024)

[15] Population data for over ten countries is missing in the DGD. For these countries, we estimate population by multiplying GDP by per capita GDP. For all other countries, the Pearson correlation coefficient between the actual population and this proxy is 0.99, indicating a strong correlation.

[16] Following Hillberry and Zurita (2022), we use the trade facilitation aid figure (line 33120) from the OECD (2023) international development statistics database.

in AFT_{pc} between 2016 and 2021, with a standard deviation of \$4.30. Notably, some countries did not receive any aid for trade, likely reflecting their relatively advanced economies, while others received as much as \$34.65.

The last country characteristic considered is a measure of openness to international trade, defined as the total amount of exports and imports divided by GDP. Countries' values of exports and imports are taken from the International Trade and Production Database for Estimation (ITPD-E) by Borchert et al. (2021, 2022).[17] Country members that trade more relative to their total output possibly have a higher dependence on international trade for economic development. As a result, they could have stronger incentives to implement TFA measures faster to increase their competitiveness in the global market. The average value of openness in our sample is 0.68, with a standard deviation of 0.41. More importantly, the minimum value of openness is 0.09, and the maximum is 2.78. This reveals a broad range, with some countries having total trade accounting for less than 10% of their GDP, while others trading more than 100% of their total output.

3.3 Agri-Food GVC Flows

GVC flows are calculated using data from the 2023 Eora global supply chain database (Lenzen et al. 2013). This database is constructed from a multi-region input-output (MRIO) model that provides a time series of sectoral IO tables.[18] Eora covers about 16,000 sectors and 190 countries from 1990 to 2022. The database has been widely used to study GVC integration (Raimondi et al. 2023; Balié et al. 2019; Montalbano and Nenci 2022), GVC flows (Boffa, Jansen and Solleder 2019; Borin, Mancini and Taglioni 2021; Sanguinet, Alvim and Atienza 2022), disruptions in GVCs (Kejžar, Velić and Damijan 2022; Ayadi et al. 2022), the determinants of GVC participation (Fernandes, Kee and Winkler 2022; Kowalski et al. 2015), and economic upgrading in GVCs (Ndubuisi and Owusu 2021; Lwesya 2022). We use a common industry classification to aggregate the sectors into three categories: *agriculture*, *food & beverages (food)*, and *all sectors*. The resulting database contains symmetric sector-by-sector IO tables measured in nominal \$ and calculated using basic

[17] The ITPD-E did not report imports and exports for Liechtenstein. We obtain 2015 export data and 2014 import data for Liechtenstein from The World Factbook by the CIA 2024.

[18] Details about the Eora database are provided in Lenzen et al. (2012) and Lenzen et al. (2013).

prices. This measurement choice is important because the GVC flow measures are free on board (FOB), which is essential when estimating the GVC implications of TFA measures in the three-way gravity setting. Although our main gravity analysis focuses on the Eora sectors of agriculture and food, we also compare results with those for all sectors to check for any substantial differences.

To measure countries' GVC participation, we first calculate gross industry exports (GIE) by summing intermediate and final product export flows. GIE is then decomposed into value-added components using a *macro* decomposition as in Kim, Steinbach and Zurita (2024).[19] We separate the *domestic content*, the share of domestic inputs used in gross exports, from the *foreign content*, the share of imported inputs used in gross exports.[20] To avoid double counting the *domestic value-added* (DVA), the domestic content is multiplied by the value-added shares of all domestic industries.[21] To get *foreign value-added* (FVA), or backward GVC participation, we multiply foreign content by the share of value added by the sector generated in foreign countries and imported by the domestic country to obtain the domestic country's exports (Casella et al. 2019). Similarly, we calculate *indirect value-added* (DVX), or forward GVC participation, as the value of intermediates exported to a foreign economy that are re-exported to a third economy and incorporated into other products. We focus on agri-food FVA and DVX, but we keep GIE to compare results with other studies focusing on agri-food exports (Beverelli et al. 2023; Grant and Lambert 2008). For all measures, we consider intra-national flows, which is the standard in the current gravity literature (Yotov 2022).[22]

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[19] This approach was first introduced by Hummels, Rapoport and Yi (1998) and Hummels, Ishii and Yi (2001) and further developed by Koopman, Wang and Wei (2014). We use the decomposition approach described in Koopman, Wang and Wei (2014) to compare our findings with earlier studies using the same methodology. Recently, Baldwin, Freeman and Theodorakopoulos (2022); Borin and Mancini (2019); Borin, Mancini and Taglioni (2021); Borin and Mancini (2023) expanded the decomposition framework and developed additional GVC metrics.

[20] To separate domestic from foreign contents, we multiply GIE by the Leontief inverse of the matrix of direct input coefficients of domestic products.

[21] DVA is the share of domestic inputs used in exports. It may be double-counted if raw materials are exported, processed into intermediate goods abroad, re-imported for further processing, and then re-exported as final goods.

[22] By considering intra-national flows, we add the value of DVA to all measures, which is essentially FVA or DVX from country i to itself. In Kim, Steinbach and Zurita (2024) the sum of DVA and FVA is total value added (TVA), and the sum of DVA and FVA is indirect value added (TVX). The terms FVA and DVX in our study correspond to TVA and TVX, respectively. We keep our notation as FVA and DVX for simplicity.

4. Evolution of Implementation Levels Across Measures

Section I of the TFA is composed of 12 articles containing 238 measures. These measures can be categorized into 36 functional policy areas addressing various aspects of trade facilitation, each demanding distinct requirements for successful implementation. Policy areas with more complex requirements typically require longer implementation timelines. As a preliminary step in our analysis, we report the annual share of commitments notified as implemented for each article and policy area between 2017 and 2021. These shares are referred to as *implementation levels* in Hillberry and Zurita (2022). The numerator of this measure is the total number of implemented measures - across articles and functional areas - notified as implemented by February 22 for each year observed. The denominator is the number of WTO members in the sample times the total number of measures within each article or area. The shares help asses the areas that are implemented faster or that received more attention from country members.

Table 1 presents shares of notified implemented measures by article. Between 2017 and 2021, *Art. 9: Movement of Goods under Customs Control*, comprising of 1 provision, experienced the largest increase (18 percentage points). A plausible explanation for this change is the low number of provisions required for its full implementation. In contrast, *Article 8: Border Agency Cooperation*, comprising of six provisions, experienced the smallest increase (5.1 percentage points). Nine articles have more provisions than Art. 8, yet they exhibit larger increases in their implementation levels. This suggests that Art. 8 presents significant implementation challenges due to difficulties in coordinating domestic and foreign agencies to work together.

Implementation levels by policy areas are presented in Table 2. The areas with the largest increase in implementation levels are *Art 5.2 Detention* (21.5 percentage points) and *Art 10.8: Rejected Goods* (18.1 percentage points). The only measure contained in *detention* stipulates that members must promptly notify an importer that goods are being held for inspection. The two measures in *rejected goods* involve allowing an importer to re-consign or return to the exporter any goods rejected due to a failure to comply with SPS standards or technical regulations. From their descriptions, these measures only include minor regulatory changes and are thus easier to implement. The areas with the smallest implementation level increases are *Art. 8* (discussed above) and *Art. 10.4:*

Single Window (5.5 percentage points). To implement a *single window*, members must establish an advanced IT system for traders to submit documents and data electronically once and coordinate domestic border or customs control agencies.

5. Pace of TFA Implementation

5.1 Logistic Growth Model

We employ a logistic growth model to estimate the average annual implementation rate of the TFA-notified measures. This model is used in economics and biology to describe population growth and innovation diffusion when there is a maximum population size that can be reached (Oliver 1964). This fits in our context because there is a limited number of TFA measures to be implemented. In the model, we assume countries' gap to full implementation reduces at a slower rate as countries implement more measures. We then project implementation in future years, assuming that the gap reduction continues to follow the estimated reduction pace.

We assume that the number of a country's implemented measures at year t, M_t, evolves as:

$$\frac{dM_t}{dt} = rM_t\left[1 - \frac{M_t}{M_{max}}\right] \quad \text{and} \quad M_0 = \frac{M_{max}}{1+K};\ K \geq 0 \in \mathbb{R}\,, \tag{1}$$

where M_{max}, the saturation point, is the total number of TFA measures for full implementation (238). r is a constant representing the annual rate of measure implementation. Equation (1) is an ordinary differential equation that admits the following solution:

$$\frac{[M_{max} - M_t]}{M_t} = Ke^{-rt}\ ;\ \ K \in \mathbb{R}\,, \tag{2}$$

where K is the level of $[(M_{\max} - M_t)/M_t]$ at time $t = 0$. According to Equation (2), the ratio of the gap to full implementation to the number of implemented measures at time t $[(M_{\max} - M_t)/M_t]$ decays exponentially with a constant rate r. However, the gap itself $(M_{\max} - M_t)$ decreases following a logistic growth (sigmoid) curve, meaning that the rate of decrease slows down as M_t increases. Expressing the gap as a ratio makes the dependent variable continuous, facilitating the estimation

of r easier using Ordinary Least Squares (OLS).

A limitation of this model specification is that we do not account for countries' strategic behavior in delaying or expediting implementation date notifications. Countries may have incentives to postpone notifications to avoid liabilities in WTO dispute settlements. Conversely, countries might expedite implementation notifications to signal a commitment to trade facilitation to attract foreign investments and increase trade. Nevertheless, our efforts serve as an initial approach to estimating TFA measure implementation rates.

Based on Equation (2), our OLS specification of $Y_{it} = [(M_{max} - M_{it})/M_{it}]$ is as follows:

$$\ln(Y_{it}) = \beta_0 + rt + \lambda_1 \ln(Y_{i0}) + \lambda_2(t \times \ln(Y_{i0})) + \beta_1 X_i + \beta_2(X_i \times t) + \varepsilon_{it}\,, \tag{3}$$

where ln is the natural logarithm; i denotes the country member; and t is the year of observation. Y_{i0} is the gap to full implementation as a ratio of the level of implementation at $t = 0$ (2017). X_i is a country characteristic, which may be logged per capita GDP ($GDP_{pc,i}$), landlocked or island indicators ($landlocked_i$, $island_i$), logged population ($Population_i$), or country i's per capita aid received to support trade facilitation ($AFT_{pc,i}$). $X_i \times t$ is the interaction term between X_i and the time index t. ε_{it} is a normal error term.

5.2 Results

Table 3 explores whether country characteristics contribute to variations in countries' pace of implementation. Each covariate is included separately, both in levels and in interaction with t. As explained before, our model specification is limited, and results should be interpreted with caution. All regression specifications are estimated using robust standard errors clustered at the country level to control for heteroskedasticity and correlation between observations for the same country. Moreover, Y_{it} is adjusted to keep as many observations as possible when taking its natural

logarithm.[23]

Column 1 of Table 3 only includes the time index, t, which has a coefficient equal to $\hat{r} = -0.385$. This suggests 18 additional measures notified as implemented when the starting point is the average of 165 implemented measures in 2021.[24] The adjusted R^2 in this first regression indicates that less than 2% of the total variation in Y_t is explained by the model specification. In column 2 of Table 3, we add $\ln(Y_0)$ and the time index. Regressions including Y_0 have fewer observations because we exclude data from the year $t = 0$. The objective of the second regression is to estimate r when controlling for the initial level of implementation. In this case, $\hat{r} = -0.181$, which translates to nine additional measures notified as implemented, starting at 165 implemented measures in 2021. The estimated $\ln(Y_0)$ coefficient is 0.653, suggesting that if Y_0 increases by 10%, Y_t increases by 6.5% for subsequent years. In other words, Y_0 determines how many measures are implemented every subsequent year. The adjusted R^2 in column 2 is 0.8, indicating a good fit for the model.

In columns 3-9 of Table 3, country characteristics are introduced individually, along with their interaction with t. Our focus is on the interaction terms since they inform if r changes with country characteristics. The only country characteristic affecting r is AFT_{pc}. Results suggest that countries receiving an additional dollar of per capita aid for trade implement roughly one additional measure annually.[25] However, results also suggest that countries receiving an additional dollar of AFT_{pc} implement six fewer measures on average.[26] Our interpretation is that countries facing

[23] When the gap to full implementation or when M_{it} are zero, $\ln(Y_{it})$ does not exist. To avoid losing observations with these issues, we adjust Y_{it} by adding a small number (0.1) to both the numerator and denominator. In the end, the adjustement is $\ln[(M_{max} - M_{it} + 0.1)/(M_{it} + 0.1)]$. This transformation is not perfect, and we acknowledge that it could distort the value of the dependent variable for large or low values of M_{it}

[24] We have $\frac{(M_{\max} - M_{it})}{M_{it}} = K\exp(-rt)$. So, the ratio of the dependent variable in year $t+1$ to the same variable in year t is equal to $\frac{\exp(-r(t+1))}{\exp(-rt)} = \exp(-r)$. When $r = -0.385$, we have $\exp(-0.385) = 0.680$, indicating that $\frac{(M_{\max} - M_{i,t+1})}{M_{i,t+1}}$ is 32% lower compared to its value at time t. From Table 1, the average number of implemented measures in 2021 is 165. With $r = -0.385$, in 2024 the dependent variable is equal to $\left(\frac{238-165}{165}\right) \times 0.68$, which corresponds to an additional 18 implemented measures.

[25] This analysis is based on the estimated coefficient for $t \times AFT_{pc}$ (-0.017).

[26] The calculation is as follows. When there at the average of 165 measures notified as implemented, the value of $Y_t = (M_{max} - M_{it})/M_{it}$ is equal to 0.442, and its log is -0.815. The coefficient for AFT_{pc} is 0.110, meaning its unitary increase increases $\ln(Y_t)$ to -0.705. As a result, Y_t increases to 0.494, meaning $M_t = 159.31$.

implementation challenges tend to adopt fewer measures and request more aid for trade. Receiving more aid appears to boost their TFA implementation rate effectively.

To estimate the time to full implementation, we use $\hat{r}$ equal to -0.181 and -0.385. which are the results from columns 1 and 2 of Table 3. We project the number of TFA measures implemented beyond 2021, assuming that $\hat{r}$ remains unchanged. To better explain results, we introduce a new measure called the *TFA-Completion index* (TCI). This measure ranges from 0 to 100, and it tells when x% of the countries reach at least x% of full TFA implementation.[27] For example, a TCI of 80 means that at least 80% of the countries notified implementation of at least 80% of the TFA. Based on this, Table 4 presents the projected years for reaching TCI values of 80, 90, or 95 with $\hat{r} = -0.181$, and $\hat{r} = -0.385$. We also present results using definitive implementation dates observed in the TFAD.

With $\hat{r} = -0.181$, TCI values of 80, 90, and 95 are expected to be reached by 2045, 2049, and 2053, respectively. These projections differ from TFAD dates by 14 to 19 years. With $\hat{r} = -0.385$, TCI values of 80, 90, and 95 are projected to be reached by 2030, 2032, and 2034, respectively. These last projections differ from TFAD values by five years or less. This suggests that a logistic growth model, incorporating the initial implementation level and using $\hat{r} = -0.385$, yields implementation estimates closer to the observed implementation levels in the TFAD. Thus, it becomes our preferred model specification, and while a TCI of 100 cannot be determined with this model, achieving an index of 99 is projected by 2044.[28] Hence, near-complete TFA implementation by all WTO members is anticipated within 10 years from the time of writing.

[27] This measure is based on the H-index, a metric for evaluating research productivity. The H-index is determined by the number of citations received by each publication, with h representing the largest value, with h publications having at least h citations each. The H-index is similar to the Eddington number, which quantifies the number of days in one's life on which they have cycled at least E miles (Jeffers and Swanson 2005).

[28] Since the model is asymptotic at $M_{max} = 238$, full implementation cannot be directly calculated.

6. TFA Measure Implementation and GVC Participation

6.1 Gravity Specification

Following Anderson and van Wincoop (2003) and Olivero and Yotov (2012), we depict GVC flows from exporter i to importer j in year t in the iso-morphic gravity specifation as:

$$X_{ijt} = \frac{Y_{it}E_{jt}}{Y_t}\left(\frac{\varphi_{ijt}}{\Pi_{it}P_{jt}}\right)^{1-\sigma}, \tag{4}$$

where X_{ijt} is the bilateral, unidirectional value of trade from i to j in year t. Trade values could be foreign value added (FVA), domestic indirect value added (DVX) or gross industry exports (GIE). Total output supply from the exporter is given by $Y_{it} = \sum_j X_{ijt}$, which also includes intra-national trade (i.e., X_{ijt} for $i = j$). Total expenditures from the importer are given by $E_{jt} = \sum_i X_{ijt}$, which also includes intra-national trade. Total world production is given by $Y_t = \sum_i Y_{it} = \sum_j E_{jt}$.

The remaining elements of Equation (4) are bilateral trade costs, φ_{ijt}, the multilateral resistance terms Π_{it} and P_{jt}, and the elasticity of substitution $\sigma > 1$. In the gravity literature, φ_{ijt} is usually defined as reflecting several components such as distance, the common language between trade partners, and tariffs (Yotov et al. 2016). Π_{it} and P_{jt} are defined as:

$$\Pi_{it} = \sum_j \left(\frac{\varphi_{ijt}}{P_{jt}}\right)^{1-\sigma}\frac{E_{jt}}{Y_t} \text{ and } P_{jt} = \sum_i \left(\frac{\varphi_{ijt}}{\Pi_{it}}\right)^{1-\sigma}\frac{Y_{it}}{Y_t}, \tag{5}$$

where Π_{it} is the outward multilateral resistance term and represents the exporter's ease of market access. Conversely, P_{jt} is the inward multilateral resistance term and represents the importer's ease of market access.

Our main focus is on the bilateral trade costs, which we define as dependent on the share of common measures notified as implemented by country pairs. Thus, φ_{ijt} is expressed as:

$$\varphi_{ijt} = \exp\left(\beta_1 WTO_{ijt} + \beta_2 FTA_{ijt} + \beta_3 \mathbf{TFA}_{ijt} + \lambda_{ij}\right), \tag{6}$$

where WTO_{ijt} is an indicator that i and j are WTO members at time t; and FTA_{ijt} is an indicator that i and j have signed a free trade agreement or are members of a customs union at time t. $\mathbf{TFA}_{ijt}$ is a vector of variables related to TFA measure implementation for country pair ij at year t. λ_{ij} is a fixed-effect to control for time-invariant factors, such as distance and common language.

The measures in $\mathbf{TFA}_{ijt}$ may be *one* of the following:

- $Imp.\ TFA_{ijt}$, which represents the number of common measures notified as implemented by i and j at year t as a share of full TFA implementation. It takes a value from 0 to 1, with 1 representing full TFA implementation by i and j at year t.[29]
- $\mathbb{1}(a \leq Imp.\ TFA_{ijt} < b)$, which is an indicator that $Imp.\ TFA_{ijt}$ is between a and b. The ranges are four intervals of length 0.25 (25% or quartiles) of $Imp.\ TFA_{ijt}$.
- $Imp.\ Art\ r_{ijt}$, which represents the number of common measures in Article r notified as implemented by i and j at time t as a share of all measures in the article. It takes a value between 0 and 1, with 1 representing the full implementation of Article r by i and j at t.

To estimate Equation (4), we use a PPML estimator proposed by Santos Silva and Tenreyro (2006). This is the standard estimator in the recent structural gravity literature and has the advantage of including zero-trade flows and the control of heteroskedastic error terms. With PPML, bilateral trade flows X_{ijt} are specified as:

$$X_{ijt} = \exp\left(\alpha_0 + \alpha_1 WTO_{ijt} + \alpha_2 FTA_{ijt} + \alpha_3 \mathbf{TFA}_{ijt} + \zeta_{it} + \eta_{jt} + \theta_{ij}\right) + \varepsilon_{ijt}\,, \tag{7}$$

where subscripts are the same as in Equation (4). α_0 is an intercept term. $\alpha_1 = (1-\sigma)\beta_1$ and $\alpha_2 = (1-\sigma)\beta_2$ are the trade elasticities with respect to WTO_{ijt} and FTA_{ijt}, respectively. The coefficient $\alpha_3 = (1-\sigma)\beta_3$ is the trade elasticity with respect to the $\mathbf{TFA}_{ijt}$ vector. The terms $\zeta_{it} = -(1-\sigma)\ln(\Pi_{it}) + \ln(Y_{it})$ and $\eta_{jt} = -(1-\sigma)\ln(P_{it}) + \ln(E_{jt})$ are exporter-time and importer-time fixed effects, respectively, that capture market size and multilateral resistance terms. The term

[29] For clarity, suppose that from the 238 TFA measures, i and j have *both* implemented measures 1 to 24 at year t. In this case, $Imp.\ TFA_{ijt} = 24/238 \approx 0.1$.

$\theta_{ij} = (1-\sigma)\lambda_{ij}$ is a country-pair fixed effect that controls for several time-invariant unobservables. ε_{ijt} is a mean-zero error term.

6.2 Baseline Gravity Estimates

We begin by investigating the relationship between the share of common commitments notified as implemented by country pairs and GVC participation.[30] Table 5 presents our estimates for Equation 7, divided into two panels. Panel A contains results using $Imp.\ TFA$ in levels, while Panel B uses quartile dummies for $Imp.\ TFA$ ($\mathbb{1}(a \leq Imp.\ TFA_{ijt} < b)$). Each panel has nine columns divided into three groups representing industry sectors: Agriculture, Food, and All Sectors. For each sector, we estimate GIE, TVA, and TVX. Results for GIE and those for All sectors are presented for comparison purposes only. In all regressions, we control for joint WTO membership and the existence of trade agreements (or customs unions) between i and j.[31]

the estimated coefficient for $Imp.\ TFA$ in Panel A is negative and significant across all GVC measures and industry sectors. The coefficient for $Imp.\ TFA$ in FVA and DVX for the agriculture and food sectors ranges between -1.629 and -0.714. This suggests that increasing the share common full TFA implementation by 10% leads to a reduction in GVC flows between 6.9% and 15%.[32] A similar relationship is observed for GIE and when considering GVC flows for all sectors. This suggests that, although the TFA aims to reduce trade costs, its implementation has not increased GVC flows and may even have had the opposite effect. However, this relationship may be non-linear.

To capture non-linearities of TFA implementation, we use dummies to identify when $Imp.\ TFA$ falls within a given quartile in Panel B. The results suggest that in the agri-food sector when $Imp.\ TFA$

[30] Appendix Table A.2 provides descriptive statistics of the GVC measures. Every observation is a country pair at a given year in our sample. We only have data for 155 of the 163 WTO members. The eight member countries missing GVC data in the Eora database are Dominica, Grenada, Guinea-Bissau, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Solomon Islands, and Tonga.

[31] Both WTO_{ijt} and FTA_{ijt} typically have positive and significant estimated coefficients.

[32] To reach this number, we make the following calculations for FVA. Suppose that we start with $Imp.\ TFA = x$, and we then increase common implementation by 10 percentage points so that $Imp.\ TFA^{'} = x + 0.1$. Assuming $\alpha_3 = -1.629$, $FVA = \exp(-1.629 \times x)$ and $FVA^{'} = \exp(-1.629 \times (x + 0.1))$. Then, $FVA^{'}/FVA = \exp(-1.629 \times 0.1) = 0.850$, implying that $FVA^{'}$ is lower than FVA by 15%.

is higher than 0.50 (more than 50% of common full TFA implementation), the relationship between GVC flows and TFA implementation is mostly negative and significant. In the last quartile, the coefficients become larger in absolute terms. Below $Imp.\ TFA = 0.5$, the relationship is mostly not significant. These results are consistent with agri-food GIE results. For all sectors, values of $Imp.\ TFA$ lower than 0.25 have a positive and significant relationship with GVC flows, with this relationship becoming negative when $Imp.\ TFA$ is higher than 0.75. These results suggest that the relationship between the TFA implementation and agri-food GVC participation is not linear. It may be neutral at lower levels of common implementation but becomes negative and more pronounced at higher levels. One possible explanation for these results is that countries first implement measures they perceive to be the easiest and least costly to implement. To reach higher levels, however, countries might need to build infrastructure or train human capital, potentially increasing implementation costs. For example, single window measures have high implementation costs. These costs may reduce the net benefits of the TFA in the short run. As more data becomes available, it would be interesting to rerun the same regressions to assess any estimated changes.

Besides non-linearities, there may also be heterogeneous effects across TFA articles. Each article covers different functional policy areas and has different implementation costs. To this end, we estimate Equation 7 using the common levels of notified implementation for each of the twelve articles in Section I of the TFA ($Imp.\ Art\ r_{ijt}$) in our TFA vector. Estimation results under this specification are presented in Table 6. The columns are organized in the same order as in Table 5.

Our estimates suggest that the only articles with a positive relationship with GVC flows are *Art. 6: Disciplines on Fees and Charges*, *Art. 7: Release and Clearance of Goods*, and *Art. 9: Movement of Goods under Customs Control*. Article 6 contains 14 provisions on penalties, fees, and charges, which encourage transparency and periodical review of any (monetary) disciplines imposed by border agencies on importers and exporters. These measures involve minor procedural changes but significantly enhance transparency, predictability, and regulatory certainty, thereby fostering greater trust among trading partners. Article 7 encompasses nine policy areas encouraging expediting the release and clearance of goods. Examples of these measures include allowing for pre-arrival electronic submission of documents, adopting electronic payment procedures, and fostering the development of risk management systems. One of its sub-articles, in particular, urges

members for the swift clearance of perishable goods, which substantially benefits the agri-food sector. While certain measures of Article 7, such as the implementation of risk management and electronic payment systems, may entail significant investment, the potential positive impact on agri-food GVCs outweighs all costs. The only measure in Article 9 encourages members to allow the movement of goods intended for import within their territory under customs control from one customs office of entry to another. This flexibility enables the clearance of goods at an inland post rather than solely at the port of entry. This enhances agri-food GVC flows by increasing efficiency in clearing perishable goods.

On the other hand, five articles have negative and significant coefficients in our regressions. These are *Art. 1: Publication of Information*, *Art. 5: Non-Discrimination and Transparency Measures*, *Art. 8: Border Agency Cooperation*, *Art. 10: Import, Export and Transit Formalities* and *Art. 11: Freedom of Transit* have negative coefficients. The 22 measures contained in Article 1 encourage the publication of laws, regulations, fees, procedures, and other relevant information online. It also asks members to establish inquiry points for governments, traders, and other interested parties. Article 5 consists of eight provisions that, among other things, require members to maintain a system of notifications to improve border control or inspections concerning foods, beverages, or feedstuffs. These inspections aim to protect human, animal, and plant life or health within the member's territory. Article 8 contains six provisions that encourage members to organize their border authorities and cooperate with those of other member countries. This cooperation can take the form of joint controls or the alignment of procedures and formalities. The 30 measures in Article 10 address import, export, and transit formalities. This article covers various aspects beneficial to GVC flows, such as accepting electronic copies of import documents and reducing documentation requirements. However, it also includes measures like developing a single window, which requires a sophisticated IT infrastructure to coordinate local border agencies. Article 11 includes 21 provisions designed to enhance the transparency of goods transit. For instance, one provision stipulates that transit traffic cannot be subject to fees or charges related to the transit process.

Some other measures have insignificant effects on agri-food GVC flows, including those in Articles 2, 3, and 12. However, estimates of the coefficient for *Art. 3: Advance rulings* suggest a positive and significant relationship with food GIE flows. Moreover, when considering all sectors, there are

some differences in the magnitude of the effects observed in the agri-food sector. However, the signs and statistical significance of the coefficients typically coincide with those in the agri-food sector. In general, our estimates suggest that TFA articles have heterogeneous effects on GVC flows.

6.3 Lasso Regressions

Including individual shares of common article implementation in Equation (7) results in a specified model with 14 independent variables, as shown in Table 6. However, we suppose that only a subset of these variables have non-zero effects on GVC participation. We can identify such variables using a machine learning (ML) variable selection algorithm called lasso regression analysis. Under this approach, the data determines the model by selecting the coefficients over repetitive simulations with different subsets of the independent variables. We specify as the form of the regression, Equation (7), and adopt a regularized methodology suggested by Breinlich et al. (2022), which involves a penalization term to the original PPML model to purge the $Imp.\ Art\ r$ variables with coefficients equal to zero. Following Breinlich et al. (2022), the conditional expected value of all GVC flows using the multiplicative PPML model described above is given by:

$$\begin{aligned} \mu_{ijt} &:= E(X_{ijt}|WTO_{ijt}, FTA_{ijt}, \mathbf{TFA}_{ijt}, \zeta, \alpha, \eta, \theta) \\ &= \exp\left(\alpha_0 + \alpha_1 WTO_{ijt} + \alpha_2 FTA_{ijt} + \alpha_3 \mathbf{TFA}_{ijt} + \zeta_{it} + \eta_{jt} + \theta_{ij}\right), \end{aligned} \tag{8}$$

where i, j, and t are the importer, exporter, and year indices described for Equations (6) and (7). μ_{ijt} is the conditional expected value of X_{ijt} given the covariates WTO, FTA and the **TFA** vector, where we only consider $Imp.\ Art\ r$.

The minimization problem that defines our three-way Lasso PPML system is then given by:

$$(\hat{\alpha}, \hat{\zeta}, \hat{\eta}, \hat{\theta}) := \arg\min_{\alpha,\zeta,\eta,\theta} \left[\frac{1}{n} \sum_{i,j,t} (\mu_{ijt} - X_{ijt} \ln \mu_{ijt}) \right] + \frac{1}{n} \sum_{l=1}^{m} \lambda \hat{\varphi}_l |\alpha_l| \,, \tag{9}$$

where n is the number of observations. The first term on the right-hand side of Equation (9) reflects the standard PPML minimization problem using the pseudo-likelihood function. The second term

is the Lasso penalty term which consists of two tuning parameters, $\lambda \geq 0$ and $\hat{\varphi}_l \geq 0$. λ is the standard Lasso penalty term and following Belloni et al. (2012), we include diagonal matrix $\hat{\varphi}_l$ to also account for regressor-specific penalty weights. Along with λ, $\hat{\varphi}_l$ refines the model iteratively across TFA article common implementation variables. Larger penalties shrink the α until zero, so at the end, it leaves non-zero *Imp. Art r* variables in the final model. Fixed effects parameters (ζ, η, θ) are not penalized because we want to include them in every iteration to keep the structural gravity framework. Final (post-lasso) estimates are obtained by solving the standard PPML regression, keeping only variables selected by the ML procedures.

The properties of the lasso covariate-selection method depend on the method used to choose the tuning parameters, λ and $\hat{\varphi}_l$. There are two widely suggested methods. The traditional *cross-validation* approach is a re-sampling procedure that iteratively holds out a subset of the data and chooses the tuning parameters to maximize the model's predictive fit on that given subset. In this case, $\hat{\varphi}_l$ is set to 1. There are two major concerns with cross-validation. First, it may select too many irrelevant variables. Second, by ignoring the regressor-specific penalty $\hat{\varphi}_l$, it does not consider heteroskedasticity and within-cluster correlation featured in the data. The second and preferred approach in this paper is the *plug-in* approach that specifies appropriate functional forms for the penalty parameters based on statistical theory and uses estimates for these parameters (Ahrens, Hansen and Schaffer 2020). Thus, the plug-in method, being more theory-based than the cross-validation approach, selects variables more parsimoniously, leading to better performance in finite samples (Breinlich et al. 2022).

The plug-in Lasso approach also has several advantages over other methods. It finds the *best-fitted* model by selecting the *correct* α_l coefficients. This is achieved by updating the fit score with a small change in α_l, proceeding only if the improvement in fit significantly outweighs the penalty. The plug-in Lasso's improvement lies in the regressor-specific penalty $\hat{\varphi}_l$ to adjust to reflect the standard error of the score. This penalty prevents selecting the wrong regressors due to estimation noise by considering heteroskedasticity in the data. λ and $\hat{\varphi}_l$ must be set high enough so that the score for α_l becomes large relative to its standard error for regressor *Imp. Art r* to be selected.

There are, however, potential weaknesses in selecting fewer variables in the plug-in approach. Since

the plug-in algorithm may penalize correlated variables of a given selected variable, a problem may arise if there are numerous highly correlated covariates. In our setting, the algorithm may wrongly penalize relevant article implementation variables because they are correlated with other articles covering similar functional policy areas. In any case, Lasso-PPML regressions are complimentary in our analysis. We use them to identify which articles may matter most for enhancing GVC participation once notified as implemented.

The PPML-Lasso regression results for agriculture, food, and all sectors are presented in panels A, B, and C of Table 7, respectively. For each sector, we divide results into plug-in Lasso and post-Lasso. Interestingly, across all GVC measures, the coefficients for articles 6, 7, and 9, which have positive coefficients in our main PPML results, are excluded from the post-lasso regressions. All TFA article implementation variables kept are four out of the five that had negative and significant coefficients in 6 (articles 1, 5, 8, and 11). Moreover, all regressions kept the WTO membership dummy. For Food GVC flows, the lasso regression also keeps the FTA dummy for DVX. These results suggest that any positive effects of the TFA might be better explained by WTO membership and, to some degree, by the presence of a free trade agreement instead of the agreement in itself. This could also mean that some WTO members may have previous regional trade agreements that include trade facilitation provisions more relevant to agri-food trade (Grant and Lambert 2008).

6.4 Event Studies

While previous regressions captured some relationships between GVC flows and common TFA implementation, it is important also to understand how GVC flows dynamically adjust to changes resulting from the TFA. Other studies stress the importance of understanding the adjustment of policy changes in general (Anderson and Yotov 2023; Egger, Larch and Yotov 2022). Such dynamics may appear if the impact of the treatment on the result varies in the short- and long-run. In our context, treatment dynamics help in capturing anticipated reactions to the notified implementation of TFA commitments and delayed responses following such notifications. Countries can notify a date for the measure's implementation, which is typically set 12 months after the time of notification. On the other hand, some countries' institutions may take time to fully adapt to implemented measures, especially if they entail using new infrastructure requiring additional training.

For these reasons, GVC flow responses to TFA measure implementation could be non-linear, involving non-monotonic adjustments over time. In our PPML regressions, we find evidence of non-linearities in the share of common TFA implementation. Thus, it is important to understand how the adjustment process relates to agri-food GVC integration. A valid causal interpretation of the estimated treatment effects relies on the exogeneity of exposure to the trade policy shift concerning prior GVC participation (Roth 2022). While we cannot directly test the validity of this assumption, the outcome trends in the pre-treatment period are informative in this regard (Rambachan and Roth 2021). Suppose the observed outcomes of treated country pairs have similar trends in the pre-treatment period to those of untreated country pairs. In that case, we can accept that the parallel trends assumption holds and that TFA implementation is exogenous to the GVC flow outcomes (Freyaldenhoven et al. 2021; Sun and Abraham 2021; Roth and Sant'Anna 2023).

We consider the begin of the event for a country pair when both countries notify each other that at least one TFA measure is implemented simultaneously at any given year. To conduct the pre-event test and investigate how treatment dynamics evolve in the post-treatment period, we use an event study design that relies on an interaction of the treatment measure with indicators of event timing relative to the year when country pairs first notified they had at least one TFA measure implemented simultaneously. Our equation is as follows:

$$X_{ijt} = \exp\left(\beta_0 + \beta_1 WTO_{ijt} + \sum_{\substack{\ell=-6 \\ \ell\neq -1}}^{4} \mathbb{1}\left\{\tau_{ijt} = \ell\right\}\beta_\tau^\ell + \zeta_{it} + \eta_{jt} + \theta_{ij}\right) + \varepsilon_{ijt}\,, \tag{10}$$

where the general notation is the same as in Equation (7). τ_{ijt} represents the number of years at time t before or after country pairs began having common TFA measures notified as implemented.[33] The dynamic treatment model includes six lags and four leads relative to the event of interest, which enables us to capture pre-trends and assess post-event treatment dynamics. Following Freyaldenhoven et al. (2021), we normalize coefficients with respect to time $\ell = -1$, and thus, $\beta_\tau^{-1} = 0$. The

[33] Consequently, in the year when country pairs commence having common TFA measures notified as implemented, $\tau_{ijt} = 0$. Then, when countries have had common TFA measures notified as implemented for one year $\tau_{ijt} = 1$.

term $\sum_{\substack{\ell=-6 \\ \ell \neq -1}}^{4} \mathbb{1}\{\tau_{ijt} = \ell\} \beta_{\tau}^{\ell}$ measures the treatment dynamics of having common TFA measures notified as implemented for the corresponding GVC outcome. The number of leads is fixed because only four years have passed from the TFA's entry into force to the end of the sample. The number of lags was chosen to match the number of periods after $\ell = -1$. The central identifying assumption is that the treatment timing is independent of the error term conditional on the high-dimensional fixed effects that control for the inward and outward trade resistance terms and unobserved trade costs. The specification allows the magnitude of the treatment response to vary before notifying implementing TFA measures and uncovers how GVC flows evolve in the post-treatment period.

Figure 1 presents the event study estimates for the treatment response on bilateral GVC outcomes following having common TFA measures notified as implemented. Each subfigure plots the dynamic treatment parameters on Equation (10), along with 95 percent confidence intervals and uniform sup-t bands for the event-time of the outcome (Freyaldenhoven et al. 2021; Montiel Olea and Plagborg-Møller 2019). Static model estimates are overlayed and shown with a dashed red line. As with our PPML regressions, we report results for GIE, FVA, and DVX across three sectors: agriculture, food, and all sectors. For each case, in the subfigure notes, we report the p-value of Wald tests to pre-event trends and anticipatory behavior. Our main focus is on results for agriculture and food GVC flows. All other estimates are presented for comparison purposes.

Subfigures (a) - (c) in Figure 1 present results for agriculture GIE, FVA, and DVX. We find no evidence of significant short-run pre-trends for FVA and DVX. Since these pre-trends are statistically insignificant and the short-run treatment pathways in the pre-treatment period are flat, the pre-trend test validates the research design because it suggests that any observed effects during the treatment period are less likely to be influenced by pre-existing trends or biases. Because the treatment effect could be dynamic at the endpoints of the event window, we conduct additional Wald tests for the null hypothesis that the treatment effect levels off. These tests present supporting evidence of elevated long-run treatment effects for FVA and DVX. In GIE results, pre-trends are statistically significant, thus not validating the research design. The treatment dynamics generally suggest that the after-the-event agriculture GVC flows are lower. Moreover, results indicate that the negative response is not delayed and is larger, in absolute terms, as years pass. In general, after the event, the reduction in agriculture GVC flows hovers around 40%. These results are similar to

those presented in subfigures (h) - (i) for all sectors.

In subfigures (d) - (f) in Figure 1, we present results for food GIE, FVA, and DVX. In this sector, we find evidence of significant short-run pre-trends for all outcomes, including GIE. This finding invalidates the research design because it suggests that any observed effects during the treatment period are more likely to be influenced by pre-existing trends or biases. In any case, we find that the effects of common TFA implementation are not positive. This means that while the research design is invalid, we do not observe any significant increase in GVC flows for the food sector after common TFA implementation. Our estimates suggest that, if valid, after the event, there would be approximately a 30% reduction in Food FVA and a 50% reduction in Food DVX.

The reader should exercise caution in interpreting any estimated effects as causal, given the possibility of pre-existing trends before the trade policy shift (Freyaldenhoven, Hansen and Shapiro 2019). This means that the estimated negative effects on TFA implementation may be due to a downward trend in GVC flows before the event. To control for such a trend, we apply the methodology used in (Dobkin et al. 2018), which allows for a pre-trend at each event time. The results under this specification are presented in Appendix Figures A.1 and A.2, each with subfigures presented in the same order as in Figure 1. The dashed red lines in Figure A.1 represent the linear trends, which are overlayed on event study estimates. The linearity assumption does not seem to be reasonable in agriculture and food GVC flows because the estimated trends fall outside the 95% confidence intervals of the non-parametric study estimates after the event. This is consistent with our findings in our PPML regressions, where we found the presence of non-linearities of the effect. The trend coefficients are not statistically significant for the agriculture sector, which leads us to reject the hypothesis that pre-trends drive the response of agriculture GVC. For food GVC flows, the trend is negative and statistically significant, which coincides with our interpretations derived from results in Figure 1. When considering all sectors, the trend is upward-sloping and significant, and estimated trends fall outside the 95% confidence intervals of the non-parametric study estimates after the event. In figure A.2, we subtract the pre-trend from the estimated post-events treatment estimates, which results in average post-event GVC flow treatment effects that are smaller in absolute terms for agriculture and food. For all sectors, the effects are larger in absolute terms. In no cases did the trend subtraction make the treatment effects positive. Thus, we still find that the

TFA does not have a positive effect on GVC flows overall.

7. Conclusion

We explore the relationship between bilateral agri-food GVC flows and the share of common TFA measures reported as implemented between country pairs. We assume that TFA signatory countries are incentivized to provide accurate implementation dates for each provision, as most commitments are binding. We divide our work into three separate analyses. In the first two preliminary analyses, we explore which functional areas of the agreement have made the slowest progress in implementation, and we estimate the pace of provision implementation. We then study the implications of common TFA implementation on forward GVC participation and backward GVC participation.

First, we report on the evolution of TFA implementation by examining the annual share of commitments made in each area of trade facilitation policy between 2017 and 2021. This is one of our two preliminary analyses. Assuming that countries initially make the easiest commitments and postpone the more challenging ones, this analysis helps identify which measures require the most attention based on their perceived implementation difficulty. The areas that have made the slowest implementation progress five years after the agreement's entry into force are those related to *border agency cooperation* and *single window*. In contrast, the areas that have made the most progress are those related to *detention* and *rejected goods*. Second, using a logistic growth model, we examine how quickly countries move towards full TFA implementation. We find that, on average, developing countries implement 18 additional measures each year and that the pace of implementation accelerates with more per capita aid for trade. Using these estimates, we predict that full TFA implementation may be reached by 2034.

In our third and main analysis, we explore the implications of common TFA implementation between country pairs and the value of bilateral agri-food GVC flows. For this analysis, we use PPML to estimate a three-way structural gravity model where agreement implementation affects trade costs. Our results suggest that when country pairs have commonly implemented half or less than half of the agreement, GVC flows remain unaffected. However, higher shares of common agreement implementation negatively correlate with our selected agri-food GVC participation measures. When disaggregating common implementation at the article level, we find that only *Art. 6:*

Disciplines on Fees and Charges, *Art. 7: Release and Clearance of Goods*, and *Art. 9: Movement of Goods under Customs Control* is associated with higher levels of agri-food GVC flows. Nevertheless, a Lasso regression suggests that the joint WTO membership of importers and exporters may better explain any positive effects of implementing the TFA article. This suggests that the benefits associated with the agreement's articles may arise from WTO membership rather than the agreement alone. We complement the analysis with event studies, which provide evidence of neutral or negative effects of TFA implementation on GVC participation.

While our analyses cover just five years since the TFA's implementation —a relatively short period— they offer insights into the global landscape post-implementation and the observed benefits thus far. It also provides insights into future agreements that may be considering providing the same *à la carte* flexibility to signatory countries. Another limitation of the analysis is that during the period analyzed, the world was affected by COVID-19, which caused disruptions in global supply chains. As mentioned in our background section, the pandemic was one of the major reasons that signatory countries mentioned in their request to delay measure implementation. Nevertheless, if effective, the TFA should have reduced the negative effects of supply chain disruptions, which is not observed in our event-study results. Moreover, while the TFA implementation seems to have negative effects on agri-food GVC participation, there is evidence that this negative effect is only observed at higher levels of common implementation. This points to implementation costs increasing as countries try to reach higher levels of TFA compliance. Additionally, we find evidence supporting the positive effects of three of the 12 TFA articles on agri-food GVCs. Future research could develop a general equilibrium analysis considering perceived implementation costs and trade cost reductions. This type of research could provide some idea of the *net* benefits of the TFA.

References

Ahrens, Achim, Christian B Hansen, and Mark E Schaffer. 2020. "lassopack: Model selection and prediction with regularized regression in Stata." *The Stata Journal*, 20(1): 176–235.

Anderson, James E., and Eric van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle." *American Economic Review*, 93(1): 170–192.

Anderson, James E, and Yoto V Yotov. 2023. "Estimating gravity from the short to the long run: A simple solution to the 'International Elasticity Puzzle'." *NBER Working Paper*, 30809.

Ayadi, Rym, Giorgia Giovannetti, Enrico Marvasi, Giulio Vannelli, and Chahir Zaki. 2022. "Demand and supply exposure through global value chains: Euro-Mediterranean countries during COVID." *World Economy*, 45(3): 637–656.

Baldwin, Richard, Rebecca Freeman, and Angelos Theodorakopoulos. 2022. "Horses for Courses: Measuring Foreign Supply Chain Exposure." *NBER Working Paper*, 30525.

Balié, Jean, Davide Del Prete, Emiliano Magrini, Pierluigi Montalbano, and Silvia Nenci. 2019. "Does Trade Policy Impact Food and Agriculture Global Value Chain Participation of Sub-Saharan African Countries?" *American Journal of Agricultural Economics*, 101(3): 773–789.

Belloni, A., D. Chen, V. Chernozhukov, and C. Hansen. 2012. "Sparse Models and Methods for Optimal Instruments With an Application to Eminent Domain." *Econometrica*, 80(6): 2369–2429.

Beverelli, Cosimo, Isabella Gourevich, Inga Heiland, Alexander Keck, Mario Larch, and Yoto Yotov. 2023. "Trade and Welfare Effects of the WTO Trade Facilitation Agreement." World Trade Organization (WTO), Economic Research and Statistics Division WTO Staff Working Paper.

Beverelli, Cosimo, Simon Neumueller, and Robert Teh. 2015. "Export Diversification Effects of the WTO Trade Facilitation Agreement." *World Development*, 76: 293–310.

Boffa, Mauro, Marion Jansen, and Olga Solleder. 2019. "Do we need deeper trade agreements for GVCs or just a BIT?" *World Economy*, 42(6): 1713–1739.

Borchert, Ingo, Mario Larch, Serge Shikher, and Yoto V. Yotov. 2021. "The International Trade and Production Database for Estimation (ITPD-E)." *International Economics*, 166: 140–166.

Borchert, Ingo, Mario Larch, Serge Shikher, and Yoto V Yotov. 2022. "The international trade and production database for estimation - release 2 (ITPD-E R02)." USITC Working Paper 2022–07–A.

Borin, Alessandro, and Michele Mancini. 2019. "Measuring what matters in global value chains and value-added trade." *World Bank Policy Research Working Paper*, 8804.

Borin, Alessandro, and Michele Mancini. 2023. "Measuring what matters in value-added trade." *Economic Systems Research*, 35: 586–613.

Borin, Alessandro, Michele Mancini, and Daria Taglioni. 2021. "Measuring exposure to risk in global value chains." *World Bank Policy Research Working Paper*, 9785.

Breinlich, Holger, Valentina Corradi, Nadia Rocha, Michele Ruta, JMC Santos Silva, and Thomas Zylkin. 2022. "Machine learning in international trade research-evaluating the impact of trade agreements."

Casella, Bruno, Richard Bolwijn, Daniel Moran, and Keiichiro Kanemoto. 2019. "UNCTAD insights: Improving the analysis of global value chains: the UNCTAD-Eora Database." *Transnational Corporations*, 26(3): 115–142.

Central Intelligence Agency. 2024. "The World Factbook: Liechtenstein: Country Summary."

Djankov, Simeon, Caroline Freund, and Cong S. Pham. 2010. "Trading on time." *The Review of Economics and Statistics*, 92(1): 166–173.

Dobkin, Carlos, Amy Finkelstein, Raymond Kluender, and Matthew J. Notowidigdo. 2018. "The Economic Consequences of Hospital Admissions." *American Economic Review*, 108(2): 308–52.

Egger, Peter H, Mario Larch, and Yoto V Yotov. 2022. "Gravity estimations with interval data: Revisiting the impact of free trade agreements." *Economica*, 89(353): 44–61.

Fernandes, Ana Margarida, Hiau Looi Kee, and Deborah Winkler. 2022. "Determinants of global value chain participation: Cross-country evidence." *World Bank Economic Review*, 36(2): 329–360.

Fontagné, Lionel, Gianluca Orefice, and Roberta Piermartini. 2020. "Making small firms happy? The heterogeneous effect of trade facilitation measures." *Review of International Economics*, 28(3): 565–598.

Freyaldenhoven, Simon, Christian Hansen, and Jesse M. Shapiro. 2019. "Pre-event Trends in the Panel Event-Study Design." *American Economic Review*, 109(9): 3307–38.

Freyaldenhoven, Simon, Christian Hansen, Jorge Pérez Pérez, and Jesse M Shapiro. 2021. "Visualization, identification, and estimation in the linear panel event-study design." *NBER Working Paper*, 29170.

Grant, Jason H, and Dayton M Lambert. 2008. "Do regional trade agreements increase members' agricultural trade?" *American Journal of Agricultural Economics*, 90(3): 765–782.

Greenville, Jared, Kentaro Kawasaki, and Raphael Beaujeu. 2017. "How policies shape global food and agriculture value chains." OECD Publishing OECD Food, Agriculture and Fisheries Working Papers 100.

Gurevich, Tamara, and Peter Herman. 2018. "The Dynamic Gravity Dataset: 1948–2016." USITC Working Paper 2018-02-A.

Hillberry, Russell, and Carlos Zurita. 2022. "Commitment Behaviour in the World Trade Organization's Trade Facilitation Agreement." *The World Economy*, 45(1): 36–75.

Hillberry, Russell, and Xiaohui Zhang. 2018. "Policy and performance in customs: Evaluating the trade facilitation agreement." *Review of International Economics*, 26(2): 438–480.

Hummels, David, Dana Rapoport, and Kei-Mu Yi. 1998. "Vertical specialization and the changing nature of world trade." *Economic Policy Review*, 4: 79–99.

Hummels, David, Jun Ishii, and Kei-Mu Yi. 2001. "The nature and growth of vertical specialization in world trade." *Journal of International Economics*, 54(1): 75–96.

International Monetary Fund. 2024. "GDP, current prices: Billions of U.S. dollars."

International Trade Centre. 2020. "Getting down to business: Making the Most of the WTO Trade Facilitation Agreement." *URL: https://intracen.org/file/gettingdowntobusinesswtotechnicalnoteslowrespdf, Access date: 2023-05-23.*

Jeffers, David, and John Swanson. 2005. "How high is your E?" *Physics World*, 18(10): 21.

Kejžar, Katja Zajc, Alan Velić, and Jože P. Damijan. 2022. "COVID-19, trade collapse and GVC linkages: European experience." *World Economy*, 45(11): 3475–3506.

Kim, Dongin, Sandro Steinbach, and Carlos Zurita. 2024. "Deep trade agreements and agri-food global value chain integration." *Food Policy*, 127: 102686. Transforming Global Agri-Food Value Chains.

Koopman, Robert, Zhi Wang, and Shang-Jin Wei. 2014. "Tracing value-added and double counting in gross exports." *American Economic Review*, 104(2): 459–494.

Kowalski, Przemyslaw, Javier Lopez Gonzalez, Alexandros Ragoussis, and Cristian Ugarte. 2015. "Participation of developing countries in global value chains: Implications for trade and trade-related policies." *OECD Food, Agriculture and Fisheries Papers*, 179.

Lenzen, Manfred, Daniel Moran, Keiichiro Kanemoto, and Arne Geschke. 2013. "Building Eora: A global multi-region input–output database at high country and sector resolution." *Economic Systems Research*, 25(1): 20–49.

Lenzen, Manfred, Keiichiro Kanemoto, Daniel Moran, and Arne Geschke. 2012. "Mapping the structure of the world economy." *Environmental Science & Technology*, 46(15): 8374–8381.

Lwesya, Francis. 2022. "Integration into regional or global value chains and economic upgrading prospects: an analysis of the East African Community (EAC) bloc." *Future Business Journal*, 8(1): 33.

Masood, Amjad, and Inmaculada Martínez-Zarzoso. 2023. "Trade Effects of Trade Facilitation Revisited." *Economics Letters*, 111477.

Montalbano, Pierluigi, and Silvia Nenci. 2022. "Does global value chain participation and positioning in the agriculture and food sectors affect economic performance? A global assessment." *Food Policy*, 108: 102235.

Montiel Olea, José Luis, and Mikkel Plagborg-Møller. 2019. "Simultaneous confidence bands: Theory, implementation, and an application to SVARs." *Journal of Applied Econometrics*, 34(1): 1–17.

Moïsé, Evdokia, and Silvia Sorescu. 2013. "Trade Facilitation Indicators: The Potential Impact of Trade Facilitation on Developing Countries' Trade." OECD Publishing OECD Trade Policy Papers 144.

Ndubuisi, Gideon, and Solomon Owusu. 2021. "How important is GVC participation to export upgrading?" *World Economy*, 44(10): 2887–2908.

OECD. 2018. *Trade Facilitation and the Global Economy.* OECD Publishing.

Oliver, F. R. 1964. "Methods of Estimating the Logistic Growth Function." *Journal of the Royal Statistical Society Series C: Applied Statistics*, 13(2): 57–66.

Olivero, María Pía, and Yoto V. Yotov. 2012. "Dynamic gravity: Endogenous country size and asset accumulation." *Canadian Journal of Economics*, 45: 64–92.

Organisation for Economic Co-operation and Development. 2023. "Query wizard for international development statistics (QWIDS)."

Raimondi, Valentina, Andreea Piriu, Johan Swinnen, and Alessandro Olper. 2023. "Impact of global value chains on tariffs and non-tariff measures in agriculture and food." *Food Policy*, 118: 102469.

Rambachan, Ashesh, and Jonathan Roth. 2021. "An Honest Approach to Parallel Trends." Working Paper.

Roth, Jonathan. 2022. "Pretest with Caution: Event-Study Estimates After Testing for Parallel Trends." *American Economic Review: Insights*, 4(3): 305–22.

Roth, Jonathan, and Pedro HC Sant'Anna. 2023. "When is parallel trends sensitive to functional form?" *Econometrica*, 91(2): 737–747.

Sanguinet, Eduardo Rodrigues, Augusto Mussi Alvim, and Miguel Atienza. 2022. "Trade agreements and participation in global value chains: Empirical evidence from Latin America." *World Economy*, 45(3): 702–738.

Santos Silva, J. M. C., and Silvana Tenreyro. 2006. "The Log of gravity." *The Review of Economics and Statistics*, 88(4): 641–658.

Shepherd, Ben. 2016. "Trade facilitation and global value chains: Opportunities for sustainable development." *Geneva: International Centre for Trade and Sustainable Development (ICTSD).*

Sun, Liyang, and Sarah Abraham. 2021. "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects." *Journal of Econometrics*, 225(2): 175–199.

USAID. 2019. *Assessing the Benefits of the Trade Facilitation Agreement for Agricultural Trade.* USAID Washington, DC.

World Trade Organization. 2014. "Azevêdo launches new WTO Trade Facilitation Agreement Facility to deliver support to LDCs and developing countries International organizations pledge their support for implementing Trade Facilitation Agreement." *URL:https://www.wto.org/english/news_e/news14_e/fac_22jul14_e.htm, Access date: 2023-04-13.*

World Trade Organization. 2015. *Speeding up trade: benefits and challenges of implementing the WTO Trade Facilitation Agreement. World Trade Report 2015.* WTO Geneva.

World Trade Organization. 2023*a*. "Trade Facilitation."

World Trade Organization. 2023*b*. "Trade Facilitation Agreement Database." *URL: https://www.tfadatabase.org/, Access date: 2023-03-24.*

Yotov, Yoto V. 2022. "On the role of domestic trade flows for estimating the gravity model of trade." *Contemporary Economic Policy*, 40(3): 526–540.

Yotov, Yoto V., Roberta Piermartini, Jose A. Monteiro, and Mario Larch. 2016. *An advanced guide to trade policy analysis: The structural gravity model.* WTO.

Tables and Figures

Table 1: Evolution of Implementation Levels by Article in Section I of the TFA

TFA Article	No. of Measures	No. of Imp. Meas. Poss.	Implementation by Year (Percent)					Δ 2017-2021 (Percent)
			2017	2018	2019	2020	2021	
Art. 1: Publication of Information	22	3,586	53.3	57.5	58.1	60.5	65.6	12.4
Art. 2: Opportunity to Comment and Consultations	4	652	58.4	64.3	66.0	68.6	72.5	14.1
Art. 3: Advance Rulings	19	3,097	50.4	54.7	54.7	57.3	61.2	10.8
Art. 4: Appeal or Review Procedures	9	1,467	65.8	74.0	74.0	75.2	78.9	13.0
Art. 5: Non-Discrim. and Transp. Measures	8	1,304	53.8	60.4	61.3	62.7	66.5	12.7
Art. 6: Disciplines on Fees and Charges	14	2,282	63.0	69.5	70.0	71.7	75.8	12.8
Art. 7: Release and Clearance of Goods	55	8,965	54.3	58.9	59.6	61.4	65.3	11.0
Art. 8: Border Agency Cooperation	6	978	53.4	53.4	54.1	54.1	58.5	5.1
Art. 9: Movement of Goods under Customs Control	1	163	73.0	87.1	87.7	89.0	90.8	17.8
Art. 10: Import, Export, and Transit Formalities	30	4,890	62.8	70.8	71.3	73.3	75.4	12.6
Art. 11: Freedom of Transit	21	3,423	63.1	69.3	69.7	71.2	75.7	12.6
Art. 12: Customs Cooperation	49	7,987	57.3	63.4	64.6	66.7	70.2	12.9
Total	238	38,794	57.4	63.1	63.8	65.7	69.4	12.0

Note. This table presents the TFA implementation levels across all WTO members disaggregated by article. The Number of Measures is the number of measures in each article, where each measure is roughly a paragraph in the agreement. The Number of Implemented Measures Possible (No. of Imp. Meas. Poss.) is the number of measures by article multiplied by the total number of WTO members in the sample (163). Implementation by Year is the share of No. of Imp. Meas. Poss. that are implemented (summing implementation of measures in that article for all 163 countries), multiplied by 100 for each year in the sample. Δ 2017-2021 is the difference between the share of full TFA article implementation (implementation by year) in 2021 and 2017.

Table 2: Evolution of Implementation Levels by Functional Policy Area

TFA Policy Area	No. of Measures	No. of Imp. Meas. Poss.	Percentage by Year					Δ 2017-2021 (Percent)
			2017	2018	2019	2020	2021	
Art. 1.1: Publication	10	1630	54.1	57.7	58.3	60.4	66.5	12.4
Art. 1.2: Information Available through Internet	5	815	53.4	56.7	57.3	58.8	61.8	8.5
Art. 1.3: Enquiry Points	4	652	49.7	53.5	53.8	58.4	64.0	14.3
Art. 1.4: Notification	3	489	55.0	63.4	64.0	66.3	71.2	16.2
Art. 2.1: Comments and Information before entry into Force	3	489	58.9	65.0	66.9	69.5	73.2	14.3
Art. 2.2: Consultations	1	163	57.1	62.0	63.2	65.6	70.6	13.5
Art. 3: Advance Rulings	19	3097	50.4	54.7	54.7	57.3	61.2	10.8
Art. 4: Procedures for Appeal or Review	9	1467	65.8	74.0	74.0	75.2	78.9	13.0
Art. 5.1: Notifications for Enhanced Controls or Inspections	4	652	53.8	61.2	61.8	63.7	69.2	15.3
Art. 5.2: Detention	1	163	68.1	82.2	82.8	84.7	89.6	21.5
Art. 5.3: Test Procedures	3	489	49.1	52.1	53.4	54.0	55.2	6.1
Art. 6.1: General Disciplines on Fees and Charges	4	652	56.0	61.5	62.1	65.3	69.2	13.2
Art. 6.2: Specific Disciplines on Fees and Charges	2	326	61.3	68.1	68.1	70.6	71.8	10.4
Art. 6.3: Penalty Disciplines	8	1304	66.9	73.8	74.5	75.2	80.1	13.2
Art. 7.1: Pre-arrival Processing	2	326	57.7	63.8	64.1	69.6	73.6	16.0
Art. 7.2: Electronic Payment	1	163	56.4	60.1	60.7	63.8	68.7	12.3
Art. 7.3: Separation of Release	7	1141	64.6	72.0	72.7	75.2	78.9	14.3
Art. 7.4: Risk Management	4	652	52.8	55.1	56.0	57.2	59.2	6.4
Art. 7.5: Post-clearance Audit	4	652	56.9	64.3	64.3	67.5	69.3	12.4
Art. 7.6: Average Release Times	2	326	49.1	52.1	52.8	57.1	60.7	11.7
Art. 7.7: Authorized Operators	17	2771	45.3	47.2	48.4	49.4	52.5	7.2
Art. 7.8: Expedited Shipments	13	2119	58.6	64.1	64.1	65.5	71.7	13.1
Art. 7.9: Perishable Goods	5	815	59.1	65.9	67.1	68.7	73.0	13.9
Art. 8: Border Agency Cooperation	6	978	53.4	53.4	54.1	54.1	58.5	5.1
Art. 9: Movement of Goods	1	163	73.0	87.1	87.7	89.0	90.8	17.8
Art. 10.1: Formalities	4	652	57.7	63.0	63.7	66.1	67.9	10.3
Art. 10.2: Acceptance of Copies	3	489	57.7	62.6	63.2	65.0	70.8	13.1
Art. 10.3: Use of International Standards	2	326	62.0	66.3	68.1	69.3	69.3	7.4
Art. 10.4: Single Window	4	652	37.7	39.0	39.0	40.8	43.3	5.5
Art. 10.5: Pre-shipment Inspection	2	326	73.6	86.8	86.8	89.9	91.1	17.5
Art. 10.6: Use of Customs Brokers	3	489	69.9	82.2	83.6	85.5	87.7	17.8
Art. 10.7: Common Border Procedures	6	978	71.0	80.8	80.8	82.9	83.5	12.6
Art. 10.8: Rejected Goods	2	326	69.0	81.3	81.9	83.7	87.1	18.1
Art. 10.9: Temporary Admission of Goods and Inward and Outward Processing	4	652	70.9	81.9	82.5	84.4	86.2	15.3
Art. 11: Transit	21	3423	63.1	69.3	69.7	71.2	75.7	12.6
Art. 12: Customs Cooperation	49	7987	57.3	63.4	64.6	66.7	70.2	12.9
Total	238	38,794	57.4	63.1	63.8	65.7	69.4	73.2

Note. This table presents the TFA implementation levels across all WTO members disaggregated by functional policy area. The Number of Measures is the number of measures in each area, where each measure is roughly a paragraph in the agreement. The Number of Implemented Measures Possible (No. of Imp. Meas. Poss.) is the number of measures by area multiplied by the total number of WTO members in the sample (163). Implementation by Year is the share of No. of Imp. Meas. Poss. that are implemented (summing implementation of measures in that article for all 163 countries), multiplied by 100 for each year in the sample. Δ 2017-2021 is the difference between the share of full TFA area implementation (implementation by year) in 2021 and 2017.

Table 3: Pooled Regression Results for the Logistic Growth Model of TFA Measure Implementation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
t	-0.385***	-0.181***	-0.185***	-0.364***	-0.180***	-0.185***	-0.165***	-0.153***	-0.237***
	(0.045)	(0.029)	(0.029)	(0.133)	(0.034)	(0.035)	(0.043)	(0.030)	(0.060)
$\ln(Y_0)$		0.653***	0.665***	0.696***	0.667***	0.656***	0.654***	0.648***	0.652***
		(0.030)	(0.032)	(0.044)	(0.031)	(0.029)	(0.029)	(0.030)	(0.030)
$t \times \ln(Y_0)$			-0.005						
			(0.003)						
$t \times \ln(GDP_{pc})$				0.021					
				(0.015)					
$\ln(GDP_{pc})$				0.142					
				(0.158)					
$t \times landlocked$					-0.004				
					(0.065)				
$landlocked$					-0.826*				
					(0.437)				
$t \times island$						0.024			
						(0.055)			
$island$						0.825**			
						(0.330)			
$t \times \ln(Population)$							-0.008		
							(0.020)		
$\ln(Population)$							-0.156**		
							(0.072)		
$t \times AFT_{pc}$								-0.017**	
								(0.008)	
AFT_{pc}								0.110***	
								(0.034)	
$t \times openness$									0.083
									(0.063)
$openness$									-0.416
									(0.335)
Constant	-1.304***	-1.334***	-1.323***	-2.526*	-1.159***	-1.488***	-1.019***	-1.518***	-1.054***
	(0.386)	(0.170)	(0.171)	(1.358)	(0.195)	(0.189)	(0.197)	(0.184)	(0.297)
Observations	815	652	652	652	652	652	652	652	652
R^2	0.015	0.801	0.801	0.802	0.807	0.808	0.808	0.806	0.801
Adjusted R^2	0.014	0.800	0.800	0.801	0.806	0.807	0.807	0.805	0.800

Note. This table presents results for a pooled OLS regression of the logistic growth model for TFA measure implementation. $Y_t = (M_{max} - M_t)/M_t$. M_t is the number of TFA provisions notified as implemented, and $M_{max} = 238$ is the total number of TFA provisions. In this way, $[(M_{max} - M_t)/M_t]$ is the gap to full implementation expressed as a ratio of the measures notified as implemented. Y_0 is Y_t at $t = 0$. GDP_{pc} is per capita GDP. *landlocked* is an indicator that the country is landlocked. *island* is an indicator if the country is an island. *Population* is population size in millions. AFT_{pc} is a measure of per capita aid received to support trade facilitation between 2016 and 2021. *openness* is the total amount of trade ($imports + exports$) over GDP. In column 1, we consider all years. For columns (2)-(9), we only consider years $t > 0$ because Y_0 is included as a covariate. Clustered standard errors at the country level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Year to reach TFA Completion Index (TCI)

TCI	Logistic Growth Model		TFAD
	$\hat{r}$ = -0.181	$\hat{r}$ = -0.385	
80	2045	2030	2026
90	2049	2032	2031
95	2053	2034	2039

Note. This table presents when a given TCI will be reached. A TCI = x says that x% of the agreement's signatory countries have implemented x% of the agreement. In the second and third columns, we assume that the gap to full implementation reduces with $\hat{r}$ = -0.181 and $\hat{r}$ = -0.385 in a logistic growth model. The fourth column presents notified implementation dates in the TFAD by WTO (2023*b*).

Table 5: Gravity Regressions Results using TFA Implementation

	Agriculture			Food			All		
	(1) GIE	(2) FVA	(3) DVX	(4) GIE	(5) FVA	(6) DVX	(7) GIE	(8) FVA	(9) DVX
Panel A: Share of Common Implementation in Levels									
WTO	0.238***	0.268***	0.404***	0.249***	0.320***	0.313***	0.336***	0.191***	0.195***
	(0.059)	(0.035)	(0.043)	(0.061)	(0.034)	(0.038)	(0.050)	(0.040)	(0.040)
FTA	0.081***	0.050***	0.076***	-0.008	0.028	0.091***	0.064**	0.021	-0.005
	(0.029)	(0.019)	(0.026)	(0.029)	(0.023)	(0.021)	(0.030)	(0.033)	(0.026)
Imp. TFA	-1.199***	-0.896***	-0.714***	-0.649***	-1.051***	-1.629***	-0.989***	-0.835***	-0.855***
	(0.106)	(0.064)	(0.067)	(0.123)	(0.070)	(0.071)	(0.123)	(0.064)	(0.065)
Observations	777,568	777,193	776,255	777,568	776,068	776,068	777,568	776,068	776,068
Pseudo R^2	0.9995	0.9992	0.9992	0.9993	0.9993	0.9990	0.9994	0.9992	0.9992
Panel B: Share of Common Implementation by using Quartile Indicators									
WTO	0.240***	0.260***	0.409***	0.247***	0.322***	0.318***	0.303***	0.174***	0.178***
	(0.060)	(0.035)	(0.042)	(0.060)	(0.034)	(0.037)	(0.049)	(0.039)	(0.040)
FTA	0.086***	0.051***	0.079***	-0.006	0.032	0.102***	0.063**	0.022	-0.003
	(0.030)	(0.019)	(0.026)	(0.029)	(0.023)	(0.021)	(0.030)	(0.033)	(0.025)
$0 < Imp.\ TFA < 0.25$	-0.102	0.027	-0.194*	-0.184	-0.235*	-0.079	0.657***	0.250***	0.247***
	(0.151)	(0.072)	(0.099)	(0.181)	(0.134)	(0.085)	(0.185)	(0.066)	(0.065)
$0.25 \leq Imp.\ TFA < 0.50$	-0.299*	-0.053	-0.173*	-0.154	-0.244*	-0.187**	0.507**	0.244***	0.246***
	(0.156)	(0.083)	(0.097)	(0.199)	(0.134)	(0.092)	(0.202)	(0.086)	(0.089)
$0.50 \leq Imp.\ TFA < 0.75$	-0.600***	-0.302***	-0.095	-0.483***	-0.507***	-0.675***	0.120	0.082	0.072
	(0.158)	(0.078)	(0.105)	(0.168)	(0.128)	(0.072)	(0.190)	(0.067)	(0.066)
$0.75 \leq Imp.\ TFA \leq 1$	-0.972***	-0.649***	-0.604***	-0.647***	-0.918***	-1.244***	-0.405**	-0.422***	-0.434***
	(0.162)	(0.072)	(0.083)	(0.170)	(0.127)	(0.062)	(0.189)	(0.057)	(0.056)
Observations	777,568	777,193	776,255	777,568	776,068	776,068	777,568	776,068	776,068
Pseudo R^2	0.9995	0.9992	0.9992	0.9993	0.9993	0.9990	0.9994	0.9992	0.9992

Note: This table presents results for a Pooled PPML regression of a three-way structural gravity model of bilateral GVC flows. *WTO* is an indicator that i and j are WTO members at year t. *FTA* indicates that i and j have a free trade agreement or are jointly part of a customs union at year t. Imp. TFA is the share of all TFA measures simultaneously implemented by i and j at time t. $a \leq$ Imp. TFA $< b$ is an indicator that Imp. TFA is between a and b. All estimates are obtained in panel settings with the PPML (HDFE) estimator, exporter-year and importer-year fixed effects, international border variables, and country-pair fixed effects. We omit the estimates of all fixed effects and the constant for presentation purposes. Standard errors clustered at the importer-exporter level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Gravity Regressions Results using TFA Implementation by Article

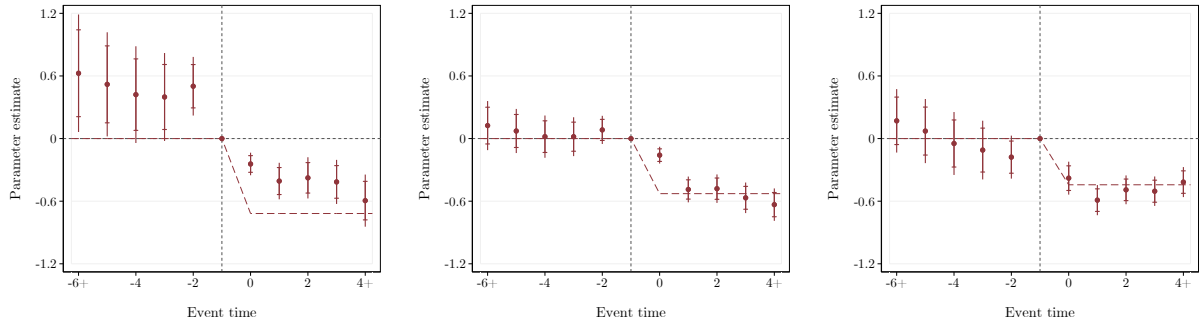
	Agriculture			Food			All		
	(1) GIE	(2) FVA	(3) DVX	(4) GIE	(5) FVA	(6) DVX	(7) GIE	(8) FVA	(9) DVX
WTO	0.248***	0.276***	0.420***	0.248***	0.334***	0.316***	0.312***	0.182***	0.186***
	(0.058)	(0.034)	(0.041)	(0.056)	(0.033)	(0.036)	(0.047)	(0.039)	(0.039)
FTA	0.080***	0.044**	0.068***	-0.003	0.023	0.077***	0.051*	0.013	-0.012
	(0.029)	(0.018)	(0.025)	(0.028)	(0.022)	(0.019)	(0.029)	(0.033)	(0.026)
Imp. Art. 1: Publication of Information	-0.552***	-0.292***	-0.150	-0.969***	-0.275***	-0.277***	-0.371***	-0.272***	-0.263***
	(0.094)	(0.065)	(0.097)	(0.127)	(0.082)	(0.076)	(0.092)	(0.081)	(0.081)
Imp. Art. 2: Opp. to Comment and Consultations	-0.031	0.058	0.166*	0.344**	-0.019	-0.069	0.136	0.074	0.085
	(0.103)	(0.070)	(0.089)	(0.139)	(0.100)	(0.090)	(0.117)	(0.090)	(0.090)
Imp. Art. 3: Advance Rulings	0.015	0.066*	-0.078	0.663***	0.074	0.094*	0.305***	0.096*	0.098*
	(0.063)	(0.038)	(0.058)	(0.086)	(0.048)	(0.050)	(0.063)	(0.051)	(0.051)
Imp. Art. 4: Appeal or Review Procedures	-0.076	-0.002	-0.280***	0.623***	0.037	0.041	0.285***	0.070	0.080
	(0.092)	(0.052)	(0.083)	(0.118)	(0.076)	(0.094)	(0.089)	(0.071)	(0.070)
Imp. Art. 5: Non-Discrim. and Transp. Measures	-0.734***	-0.332***	-0.216***	-0.214*	-0.514***	-0.665***	-0.182**	-0.138*	-0.159**
	(0.112)	(0.069)	(0.084)	(0.112)	(0.068)	(0.076)	(0.091)	(0.080)	(0.079)
Imp. Art. 6: Disciplines on Fees and Charges	0.743***	0.410***	0.939***	-0.075	0.515***	0.929***	0.572***	0.621***	0.616***
	(0.134)	(0.085)	(0.118)	(0.132)	(0.093)	(0.114)	(0.129)	(0.114)	(0.112)
Imp. Art. 7: Release and Clearance of Goods	0.153	0.297***	0.653***	0.287	0.622***	0.340**	-0.453**	0.046	0.044
	(0.152)	(0.109)	(0.127)	(0.267)	(0.168)	(0.148)	(0.208)	(0.193)	(0.188)
Imp. Art. 8: Border Agency Cooperation	-0.344***	-0.349***	-0.554***	-0.010	-0.239***	-0.469***	-0.258***	-0.202**	-0.219***
	(0.080)	(0.066)	(0.090)	(0.098)	(0.066)	(0.081)	(0.089)	(0.084)	(0.085)
Imp. Art. 9: Mov. of Goods under Customs Control	0.069	0.317***	0.319***	0.200	0.269**	0.396***	1.089***	0.699***	0.696***
	(0.128)	(0.067)	(0.112)	(0.151)	(0.118)	(0.099)	(0.162)	(0.089)	(0.087)
Imp. Art. 10: Import, Export, and Transit Form.	-0.119	-0.510***	-0.747***	-0.835***	-0.708***	-1.034***	-1.188***	-0.831***	-0.832***
	(0.247)	(0.159)	(0.259)	(0.298)	(0.180)	(0.252)	(0.317)	(0.257)	(0.247)
Imp. Art. 11: Freedom of Transit	-0.116	-0.395***	-0.758***	-0.504***	-0.665***	-0.446***	-0.482***	-0.731***	-0.715***
	(0.127)	(0.079)	(0.114)	(0.165)	(0.094)	(0.106)	(0.128)	(0.098)	(0.097)
Imp. Art. 12: Customs Cooperation	-0.075	-0.041	0.096	-0.137	-0.077	-0.170**	-0.024	0.019	0.010
	(0.082)	(0.054)	(0.086)	(0.102)	(0.064)	(0.071)	(0.087)	(0.078)	(0.076)
Observations	777,568	777193	776,255	777,568	776,068	776,068	777,568	776,068	776,068
Pseudo R^2	0.9995	0.9993	0.9992	0.9993	0.9993	0.9990	0.9995	0.9992	0.9992

Note: This table presents results for a PPML regression of a three-way structural gravity model of bilateral GVC flows from 2000 to 2021. *WTO* is an indicator that both i and j are WTO members at time t. *FTA* indicates that i and j have a free trade agreement or are jointly part of a customs union at year t. Imp. Art. r represents the share of the TFA article's r measures simultaneously notified as implemented by i and j at time t. All estimates are obtained in panel settings with the PPML estimator, exporter-time and importer-time fixed effects, international border variables, and country-pair fixed effects. For presentation purposes, we omit the estimates of all fixed effects and constants. Standard errors clustered at the importer-exporter level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Lasso-PPML Gravity Regressions Results using TFA Implementation by Article

	GIE		FVA		DVX	
	(1) Lasso	(2) Post-Lasso	(3) Lasso	(4) Post-Lasso	(5) Lasso	(6) Post-Lasso
Panel A: Agriculture Sector						
WTO	0.058	0.265*** (0.058)	0.171	0.293*** (0.035)	0.273	0.422*** (0.042)
Imp. Art. 1: Publication of Information	-0.270	-0.351*** (0.093)	-0.180	-0.136* (0.070)		
Imp. Art. 4: Appeal or Review Procedures					-0.013	-0.148* (0.089)
Imp. Art. 5: Non-Discrim. and Transp. Measures	-0.331	-0.499*** (0.098)	-0.119	-0.193*** (0.057)		
Imp. Art. 8: Border Agency Cooperation	-0.232	-0.355*** (0.081)	-0.281	-0.373*** (0.060)	-0.254	-0.445*** (0.073)
Imp. Art. 11: Freedom of Transit			-0.111	-0.216*** (0.071)	-0.305	-0.249** (0.103)
Observations		777,568		777,193		776,255
Pseudo R-squared		0.9995		0.9993		0.9992
Panel B: Food Sector						
WTO	0.036	0.253*** (0.061)	0.235	0.345*** (0.033)	0.205	0.327*** (0.037)
FTA					0.016	0.080*** (0.020)
Imp. Art. 1: Publication of Information	-0.377	-0.702*** (0.086)			-0.115	-0.054 (0.089)
Imp. Art. 5: Non-Discrim. and Transp. Measures			-0.304	-0.358*** (0.054)	-0.434	-0.494*** (0.070)
Imp. Art. 8: Border Agency Cooperation			-0.215	-0.272*** (0.056)	-0.430	-0.556*** (0.075)
Imp. Art. 10: Import, Export, and Transit Form.					-0.268	-0.275* (0.151)
Imp. Art. 11: Freedom of Transit			-0.326	-0.463*** (0.090)	-0.124	-0.208** (0.105)
Observations		777,568		776,068		776,068
Pseudo R-squared		0.9993		0.9993		0.9990
Panel C: All Sectors						
WTO	0.188	0.352*** (0.050)	0.066	0.211*** (0.040)	0.068	0.214*** (0.040)
Imp. Art. 1: Publication of Information	-0.001	-0.148 (0.120)	-0.127	-0.038 (0.081)	-0.128	-0.036 (0.078)
Imp. Art. 8: Border Agency Cooperation	-0.456	-0.576*** (0.083)	-0.196	-0.376*** (0.082)	-0.217	-0.392*** (0.081)
Imp. Art. 11: Freedom of Transit			-0.324	-0.436*** (0.088)	-0.309	-0.430*** (0.087)
Imp. Art. 12: Customs Cooperation	-0.067	-0.192*				
Observations		777,568		776,068		776,068
Pseudo R-squared		0.9995		0.9992		0.9992

Note. This table presents results for a Lasso-PPML regression of a three-way structural gravity model of bilateral GVC flows from 2000 to 2021. *WTO* is an indicator that both i and j are WTO members at time t. *FTA* indicates that i and j have a free trade agreement or are jointly part of a customs union at year t. Imp. Art r_{ijt} is the share of the TFA article's r measures notified as implemented by i and j at time t. All estimates are obtained in panel settings with the PPML estimator, exporter-time and importer-time fixed effects, international border variables, and country-pair fixed effects. For presentation purposes, we omit the estimates of all fixed effects and constants. Standard errors clustered at the importer-exporter level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.



Pre-trends p-value: 0.003 Leveling off p-value: 0.000 Static effect p-value: 0.000
Pseudo R-squared: 1.000 Observations: 777,568

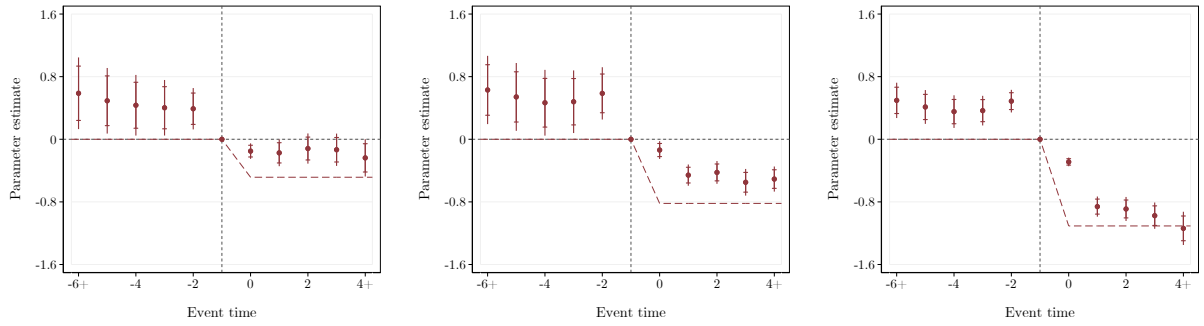
(a) GIE Agriculture

Pre-trends p-value: 0.487 Leveling off p-value: 0.000 Static effect p-value: 0.000
Pseudo R-squared: 0.999 Observations: 777,193

(b) FVA Agriculture

Pre-trends p-value: 0.527 Leveling off p-value: 0.000 Static effect p-value: 0.000
Pseudo R-squared: 0.999 Observations: 776,255

(c) DVX Agriculture



Pre-trends p-value: 0.002 Leveling off p-value: 0.000 Static effect p-value: 0.001
Pseudo R-squared: 0.999 Observations: 777,568

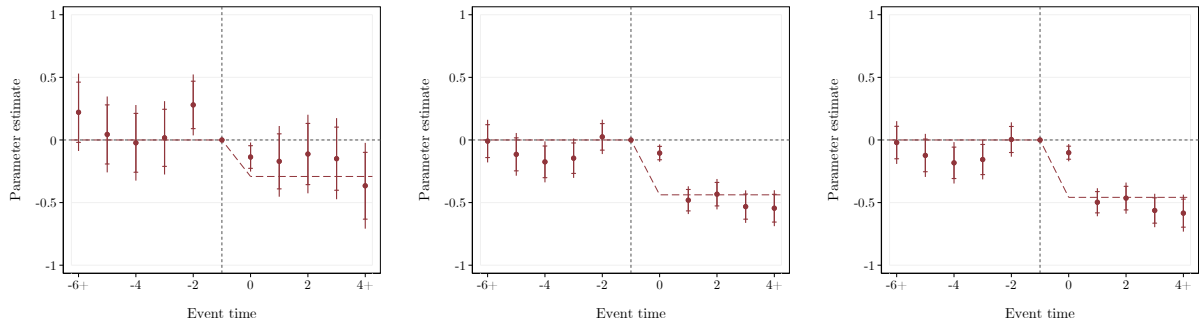
(d) GIE Food

Pre-trends p-value: 0.001 Leveling off p-value: 0.171 Static effect p-value: 0.000
Pseudo R-squared: 0.999 Observations: 776,068

(e) FVA Food

Pre-trends p-value: 0.000 Leveling off p-value: 0.000 Static effect p-value: 0.000
Pseudo R-squared: 0.999 Observations: 776,068

(f) DVX Food



Pre-trends p-value: 0.479 Leveling off p-value: 0.000 Static effect p-value: 0.111
Pseudo R-squared: 0.999 Observations: 777,568

(g) GIE All Sectors

Pre-trends p-value: 0.093 Leveling off p-value: 0.452 Static effect p-value: 0.000
Pseudo R-squared: 0.999 Observations: 776,068

(h) FVA All Sectors

Pre-trends p-value: 0.058 Leveling off p-value: 0.209 Static effect p-value: 0.000
Pseudo R-squared: 0.999 Observations: 776,068

(i) DVX All Sectors

Figure 1: Event Studies

Note. The figure presents the dynamic treatment parameters, 95 percent confidence intervals, and uniform sup-t bands for the event-time coefficients. We report the slope and standard error of the overlaid linear pre-trend and several regression statistics in the figure notes. All standard errors are clustered at the exporter-importer-sector level.

Appendix Tables and Figures

Table A.1: Descriptive Statistics for the Logistic Growth Model

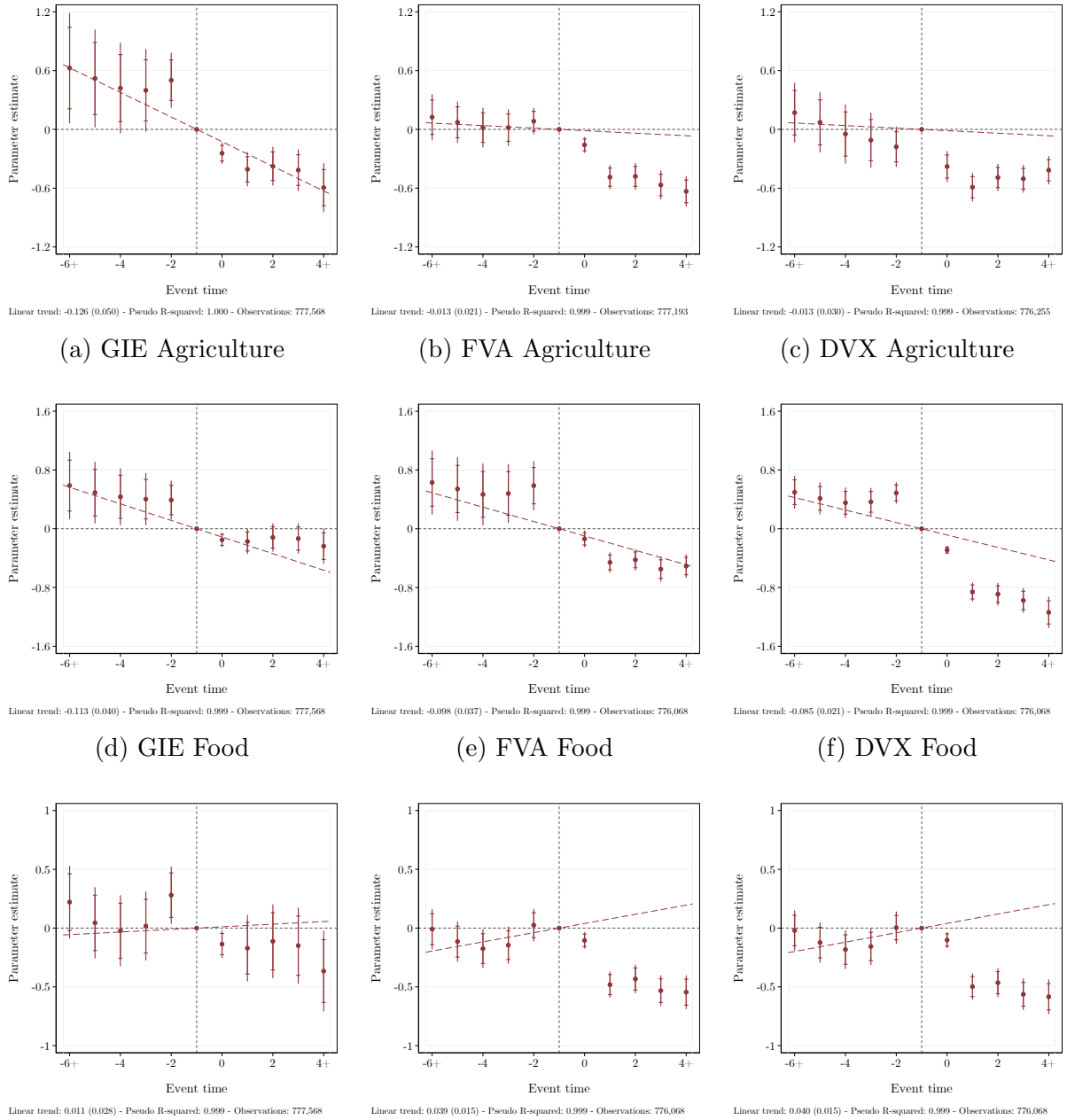
	N	Mean	SD	Min	Max
Panel A: Measures Notified as Implemented					
2017	163	136.65	97.22	0	238
2018	163	150.14	83.74	0	238
2019	163	151.77	83.54	0	238
2020	163	156.28	82.81	0	238
2021	163	165.23	79.60	0	238
Panel B: Country Characteristics in 2016					
GDP_{pc} ($ thousands)	163	15.10	22.27	0.28	165.03
$\ln(GDP_{pc})$	163	8.68	1.48	5.64	12.01
landlocked	163	0.20	0.40	0.00	1.00
island	163	0.19	0.39	0.00	1.00
Population (millions)	163	42.68	153.96	0.04	1,378.67
$\ln(Population)$	163	2.02	1.99	-3.28	7.23
AFT_{pc}	163	1.63	4.30	0.00	34.65
Openness	163	0.68	0.41	0.09	2.78

Note. This table presents the descriptive statistics of variables used in our logistic growth model to estimate the average annual rate of TFA measure implementation. N presents the number of observations of countries in this case. SD is the standard deviation. Min is the minimum. Max is the maximum. Panel A contains descriptive statistics of the number of measures notified as implemented for 163 countries, including 121 countries with *article breakdowns* in the WTO (2023*b*), 39 developed countries, and two developing countries with no data (Venezuela and Yemen). Developed member countries have full TFA implementation upon the agreement's entry into force. Panel B presents summary statistics for country characteristics in 2016. See text for data sources for country characteristics and variable definitions.

Table A.2: Descriptive Statistics of the GVC Measures

	N	Mean	SD	Min†	Max
Panel A: Agriculture Sector					
GIE	777,568	0.11	6.56	0.00	1,472.48
FVA	777,568	0.02	0.53	0.00	101.21
DVX	777,568	0.01	0.34	0.00	56.92
Panel B: Food Sector					
GIE	777,568	0.16	7.52	0.00	1,482.01
FVA	777,568	0.01	0.29	0.00	37.02
DVX	777,568	0.02	0.59	0.00	68.29
Panel C: All Sectors					
GIE	777,568	3.52	190.96	0.00	31,748.20
FVA	777,568	0.42	13.93	0.00	2,161.70
DVX	777,568	0.44	13.98	0.00	2,161.70

Note. This table presents descriptive statistics of the GVC measures used in billions of $ in our three-way structural gravity regressions. We have a total of 777,568 observations, which represent country-pair combinations between 2000 and 2021. N presents the number of observations of countries in this case. SD is the standard deviation. Min is the minimum. Max is the maximum. Panel A contains descriptive statistics that consider the agricultural sector. Panel B presents descriptive statistics that consider the food sector. Panel C considers All Sectors. † The minimum value of some GVC flows is not zero, but since they were lower than $5 million, they appear as 0.00.



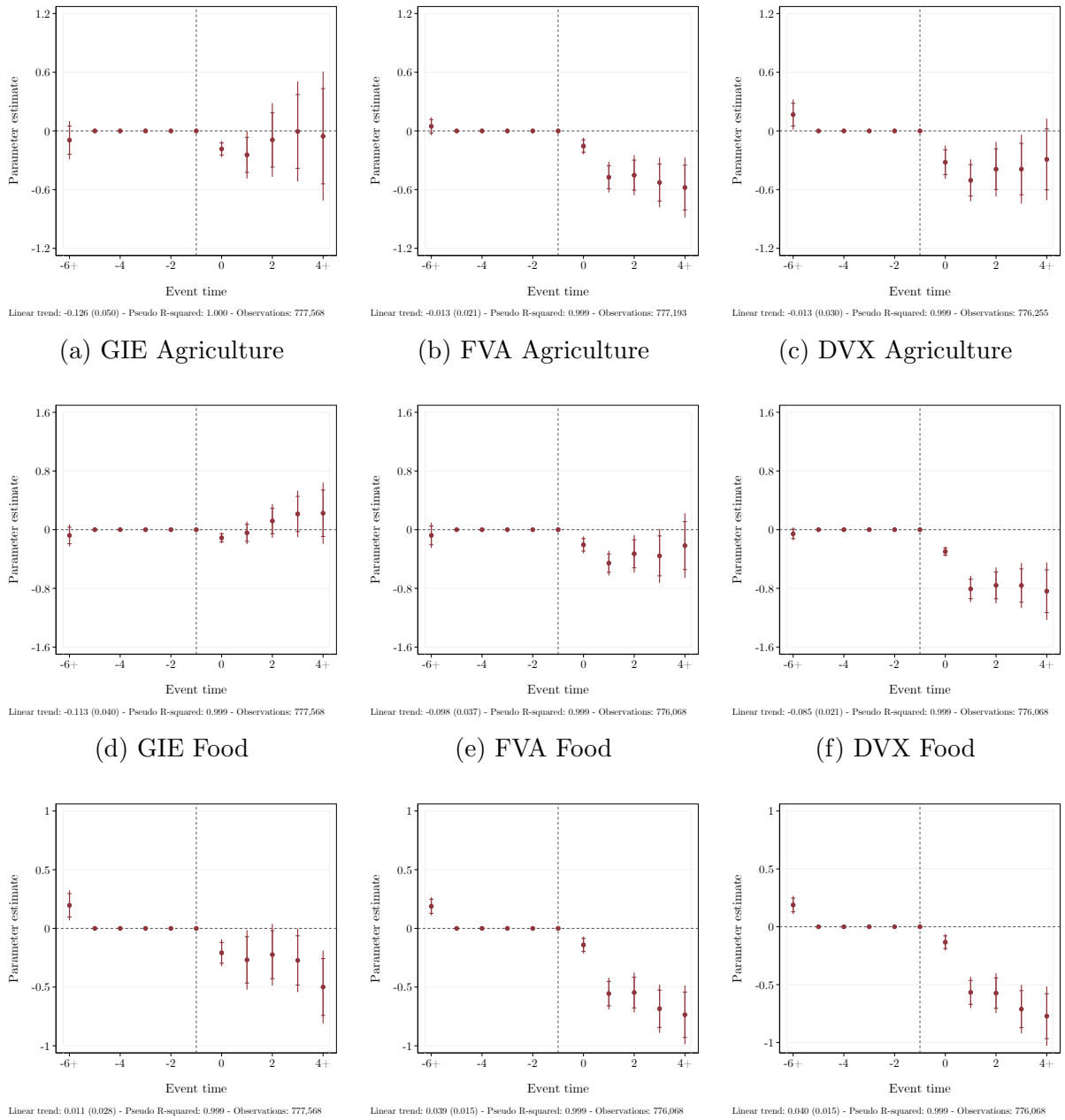
(a) GIE Agriculture (b) FVA Agriculture (c) DVX Agriculture

(d) GIE Food (e) FVA Food (f) DVX Food

(g) GIE All Sectors (h) FVA All Sectors (i) DVX All Sectors

Figure A.1: Event Studies with Overlaid Linear Pre-Trends

Note. The figure presents the dynamic treatment parameters, 95 percent confidence intervals, and uniform sup-t bands for the event-time coefficients. We report the slope and standard error of the overlaid linear pre-trend and several regression statistics in the figure notes. All standard errors are clustered at the exporter-importer-sector level.



(a) GIE Agriculture (b) FVA Agriculture (c) DVX Agriculture

(d) GIE Food (e) FVA Food (f) DVX Food

(g) GIE All Sectors (h) FVA All Sectors (i) DVX All Sectors

Figure A.2: Pre-trend Adjusted Event Studies

Note. The figure presents the dynamic treatment parameters, 95 percent confidence intervals, and uniform sup-t bands for the event-time coefficients. We report the slope and standard error of the overlaid linear pre-trend and several regression statistics in the figure notes. All standard errors are clustered at the exporter-importer-sector level.