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ORIGINAL ARTICLE

Does the World Trade Organization Enable Biosecurity and Trade for Importers and Exporters?*

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Abstract

Our paper sheds light on Sanitary and Phytosanitary (SPS) cooperation among trading countries. We contribute to the existing literature a data-driven analysis on the effectiveness of various forms (in monetary value, duration, and diversification) of SPS related technical assistance received by 33 countries from 1993 to 2015. The World Trade Organization's (WTO's) SPS Agreement encourages biosecurity for countries through technical assistance, to safeguard human health and productivity from contamination by biological hazards (pests, pathogens, or invasive species). Our panel model finds that WTO's SPS program encourages simultaneously agricultural trade and biosecurity. We implement a Multiple Indicator Solution (MIS) to correct bias from the endogenous technical assistance. The effectiveness of technical assistance depends on geography and the level of development among the heterogeneous countries referred to in our data. This investment in biosecurity benefits both donors and recipients of technical assistance. Based on our results donors should be encouraged to invest in countries with below average resources and abilities.

Keywords: panel data models; trade and environment; world trade organization; biosecurity

JEL Codes: C23; F13; F18; Q17

1. Introduction

As the volume of international trade increases so do potential risks to biosecurity worldwide. Biosecurity refers to protection from biological threats such as pests and diseases in traded goods. These threats can radically alter local ecosystems, causing ecological and economic harm to various sectors of a country. This is particularly true for countries such as the US because of the wide distribution of internationally traded products (Pimentel et al., 2005).

Invasive pests are non-native species that spread rapidly in a new area where they are free of predators or resource limitations that have controlled their population in their native habitat. Invasive species often compete with native species for food or habitat and interfere with an ecosystem's normal functioning. Marbuah et al. (2014) estimate such damages can be as high as 12% of GDP for 10 developed countries. Recognizing this biosecurity threat, countries may use different approaches to mitigate risks, including border control measures comprised of random inspections and penalties. COVID-19 increased interest in these measures. The *Food and Agriculture Organization* (FAO) has suggested the need to facilitate and enhance biosecure trade and avoid ad hoc trade restrictions or hasty policy responses that can exacerbate supply chain disruptions (FAO, 2020).

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Biosecurity is affected by both hidden actions and private information. Hidden actions occur if exporters undertake unobservable (to the importer) effort to reduce biosecurity risk. Private information exists if exporters are heterogeneous in their cost of undertaking such actions. Asymmetric information refers to variation in information available between exporters, importers, and regulators. Due to local conditions affecting biosecurity risk such as pest populations, for example, the exporter may have more information than the importer regarding both the cost of abating biosecurity risk and the amount of abatement undertaken. A thorough understanding of trade and biosecurity is more important than ever and lack of consideration of asymmetric information can confound the effect of differing policy instruments on trade and biosecurity.

Theoretical research on trade that ignores asymmetric information regarding exporters' varied biosecurity costs and risks cannot offer insights on policy alternatives that would foster trade amid asymmetric information in biosecurity. Further, when researchers omit the asymmetric information in empirical analysis, they are omitting a component that belongs in the model as a determining factor. This implies that the policy relevant results from analyses without asymmetric information may be erroneous. Countries can vary in terms of biosecurity risk and there is a need to examine adequate mechanisms to promote vigilance among trading countries given the variation. Non-distortionary policy approaches exist that could be used to better harness agricultural trade to help farmers build up their resilience, boost farm output, and support food security (Belanger and Pilling, 2019).

We estimate a relationship between trade and biosecurity and present strategies to balance both agricultural trade and biosecurity worldwide. We provide answers to the following questions: What are the incentive mechanisms between importers and exporters to overcome information asymmetry and coordinate international agricultural trade and biosecurity? Do policy instruments of the WTO promote an optimal balance of agricultural trade and biosecurity for importers and exporters across international boundaries? How do WTO policies alter agricultural production and trade flows? In reducing the negative externalities in agriculture, is the policy also distorting trade and therefore not aligned with WTO's primary goal across countries?[1] Our analysis provides answers to these questions to help advance our understanding of how policy in the pursuit of maximizing trade can include incentives for both importers and exporters to pursue biosecurity to address externalities in agricultural trade.

We recognize WTO's role in international trade and various policies addressing biosecurity. The WTO has multilateral agreements for meeting sanitary and phytosanitary standards within a context of no barriers to trade. Biosecurity risk between trading member states makes WTO agreements quite relevant. Current policy context of the Sanitary and Phytosanitary Standards (SPS) agreement promotes trade with environmental benefits directly since trade flows meet sanitary and phytosanitary standards. Precisely how the promotion happens in terms of economic incentives to overcome biosecurity risk and information asymmetry between importing and exporting countries is this paper's focus. According to Hulme (2009), proportionally more investment in better biosecurity at trade borders has the potential to bring greater dividends to society. Investment may be through implementing policies for sustaining global agricultural production and simultaneously facilitating trade.

Unlike popular economic policies, such as Pigouvian tariffs and non-tariff trade barriers, policy options of our analysis are encouraged under WTO's Sanitary and Phytosanitary (SPS) agreement. We present the first paper to analyze the quantitative impact of this agreement in a multilateral context. Technical assistance provided by an importing country to exporting countries appears in articles 9 and 10 of WTO's SPS agreement. These articles allow for multilateral technology transfer and investments in technical assistance programs as many exporting countries lack expertise and information to adequately safeguard against spreading invasive species.

[1]We include this question as a major concern of FAO's Director *Graziano da Silva* (Belanger and Pilling, 2019).

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Such technical assistances also lower informational asymmetries between importing and exporting countries. Importing countries often undertake technical assistance to prevent biosecurity risk and reduce domestic harm from invasive species. For example, the *North American Plant Protection Organization* (NAPPO) has sponsored technical assistance and preclearance to prevent the biosecurity risk of invasive species in North America. Additionally, the *European Union* has formally funded foreign agricultural programs in countries they import products from. Our paper demonstrates how these kinds of programs in WTO policy have worked to reduce biosecurity risks, eliminate information asymmetries, and enhance trade in agricultural products across heterogeneous countries at the same time. Our analysis assumes economic incentives from technical assistance overcome information asymmetry by encouraging exporters to reveal hidden information about their ability to abate biosecurity risks from their traded goods.

We test an analytical model with relevant components drawn from mechanism design and actual policy. The model helps explore incentive mechanisms for voluntary disclosure by diverse exporters about biosecurity risk to prevent hazards in international trade. Our empirical model tests if SPS technical assistance enhances trade by overcoming information asymmetries between importers and exporters. In doing so, we allow variations across countries to explore heterogeneous policies to address heterogeneous biosecurity risk rather than a one size fits all policy. We are not aware of other publications in the literature that quantitatively test articles 9 and 10 of WTO's SPS measures, which encourage voluntary biosecurity among members (importers and exporters) along with information sharing. Our panel model captures variations in timing of policy implementation and magnitude of policy investments across different countries. The relationship between technical assistance and trade depends on specific country characteristics and varies across country groups, leading to more reliable and robust results .

Our empirical model's focus is on exports of agricultural goods benefiting from assistance received by 33 countries at any time between 1933 and 2015. The rest of the world, not only the donors of technical assistance, imports these goods. To find a relationship between technical assistance in various forms (in monetary value, duration and diversification) and export of goods receiving assistance, we estimate a panel model with country dummies and a panel model with varying slopes, controlling for exogenous factors such as the share of manufactured exports in total exports and real gross domestic product per capita. Allowing slopes to vary across country groups gives us the ability to evaluate how the beneficial impact of WTO's SPS measures/procedures on trade varies across heterogeneous country groups. Technical assistance is endogenous by definition, i.e. it correlates with unobserved country characteristics, specifically a trading country's ability to export agricultural products. We use the MIS to correct this bias from endogeneity, where a recipient country's enabling trade index and value added by agriculture (% GDP) are indicators of its unobserved ability to trade. In this way, we are able to distill the SPS impact on agricultural export volume.

Our results indicate that SPS policy may increase trade volume while reducing negative externalities in agricultural trade, thereby achieving WTO goals with articles 9 and 10 (WTO, 2010). The impact of technical assistance on export of goods receiving assistance depends on the nature of assistance, country characteristics, level of development, and geography. Evaluating this impact will provide donors a guide, suggesting which countries receiving what kind of assistance would benefit most from it.

In section 2, we discuss relevant papers in the literature. Section 3 discusses the theoretical model of Fernandez and Sheriff (2013), examining the interaction between importing and exporting countries contending with asymmetric information over biosecurity risk. Their theoretical proposition on providing technical assistance lays the foundation for WTO's SPS regulations having an impact on trade. In section 4, we present a panel model with country dummies and a panel model with varying slopes to test how articles 9 and 10 of WTO's SPS measures influence trade in agricultural products. We apply MIS to deal with bias from endogenous technical assistance. Section 5 discusses our results and section 6 concludes with policy implications.

2. Literature

The WTO formally recognizes that environmental protection is a legitimate policy goal through its SPS agreement. The SPS agreement aims to facilitate multilateral cooperation on trade policy with environmental goals through common health and environmental standards. The main provisions of the agreement allow countries the right to take measures to safeguard human health and domestic productivity from contamination by foreign biological hazards (pests, pathogens, etc.) based on scientific principles and not disguised protection (WTO, 2010). In this agreement, phytosanitary pests are organisms that are not yet present in an importing country in a trade context. The WTO has attempted to balance flexibility for trading countries to realize environmental goals while at the same time imposing rules to prevent barriers to trade. WTO measures include incentives to correct market failures (biosecurity externalities, asymmetric information) through articles 9 and 10.

Theoretical literature about such incentives and policy tools to mitigate biosecurity risk in a trade context is limited. Fernandez and Sheriff (2013) examine the interaction between importing and exporting countries contending with asymmetric information over biosecurity risk in a manner that involves prevention along the supply chain in production. The model in Fernandez and Sheriff (2013) can help identify optimal policy if the import regulator cannot observe exporter variation. The model differs from earlier approaches both in the array of instruments at the regulator's disposal as well as their assumption that producers know their own product quality as well as their abatement action (in the model exporters know costs and actions, but not the ultimate SPS status of their cargo).

Missing in the traditional literature is the discussion on the importance of mitigating asymmetric information between exporters and importers, a key component of WTO's SPS measures. Grant and Anders (2011), Vigani et al. (2012) and Shavell (1984) investigate changes in trade patterns from import refusals, detentions, or safety regulations, but none consider asymmetric information between importers and exporters. Asymmetric information is not considered in analyzing protectionist import tariffs (Mumford (2002) and Costello and McAusland, 2003) or inspections (Olson and Roy, 2010; Springborn et al., 2016) regarding the specific concern of invasive species. Although tariffs can potentially reduce risk by restricting trade, they are blunt instruments and do not give exporters an incentive to undertake risk-abating activity that WTO's SPS measures support as do our research tests using cross-country data. Another drawback of tariffs is that they can also increase expected damages by expanding vulnerable import competing sectors.[2] Finally, information on an exporter's idiosyncratic risk may be asymmetric if, for example, pest populations vary across time and space, with current local environmental conditions leading to risk-reduction costs that vary by producer. Regulators currently lack precise information about varying risk and abatement costs. As a result of this varying information, exporters may undertake different levels of effort and thus have better knowledge about the ultimate riskiness of their cargo than the import regulator. Traditional policies, such as tariffs, do not account for this asymmetric information problem. Invasive species scientists have narrowly described the need for management, such as the imposition of quarantines and bans (Pysek et al., 2020) without acknowledging how WTO's SPS measures may lead to prevention and early warning prior to export.

Josling et al. (2004) recognize that, despite national systems to record interceptions and outbreaks, there is less research on effectiveness of tackling the sources of biosecurity threats. Libecap (2014) laments the lack of attention towards empirical investigations on the extent to which international standards or agreements have worked against or in favor of trade.[3] Some within-country

[2]Costello and McAusland (2003) briefly discuss an example in which differences in exporter characteristics may lead to a suboptimal outcome without formally solving the import regulator's problem.

[3]The WTO works with other agencies, such as the FAO, who sets international standards applicable worldwide, such as *ISPM* 15 on wood packaging.

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and cross-country studies evaluate the impact of the stringency and subjective perception of these standards on trade (Gebrehiwet et al., 2007; Disdier et al., 2008; Schlueter et al., 2009; Liu and Yue, 2012; Melo et al. 2014; Crivelli and Groeschl 2016); Melo et al., 2014) look at regulations and perceived stringency of standards applicable to four fruits exported from Central Chile, while Schlueter et al. (2009) investigate meat standards, and Gebrehiwet et al. (2007) investigate how foods exports from South Africa are affected by the aflatoxin levels set by five OECD countries. These studies also note that developing countries usually lack resources and expertise to meet such standards. Clearly, policies helping compliance with SPS standards for good agricultural practices are needed.

We fill a gap in the literature, testing articles 9 and 10 of WTO's SPS measures with country-level panel data to determine the potential for investments reducing biosecurity risks while improving producers' competitiveness and quality of traded products concurrently. WTO's SPS regulations provide economic incentives to importers and exporters of agricultural products to overcome information asymmetries. Through SPS, exporters could reveal hidden information regarding their ability to abate biosecurity risks, such as information on invasive species in their traded goods. Our empirical model is applicable to theoretical models that address such information asymmetries. This is in line with Porter's *win–win* Hypothesis (Montgomery and Porter, 1991; Porter and Linde, 1995), which allows connecting strong environmental policies with positive trade flows. Controlling for other factors in order to assess the impact of the policies, our research determines how well some WTO policies enable simultaneous biosecurity and enhanced trade over heterogeneous countries with variation in agricultural shares of GDP.

3. Theoretical Framework

The following discussion provides a theoretical framework for econometric estimation in the subsequent section where we consider various types and levels of technical assistance investments. The theoretical model in Fernandez and Sheriff (2013) examines interactions between importing and exporting countries with asymmetric regulator enters biosecurity risk. Asymmetric information for the importing country's trade regulator enters an economic framework of a contract with policy mechanisms to monitor exporter behavior. An efficient contract provides optimal biosecurity risk sharing between the exporters and regulator who designs a reward structure for the exporters. The reward structure can include technical assistance in a revelation mechanism design approach for solving asymmetric information on biosecurity risk. The contract can allocate resources, induce efficient decisions, and help reveal hidden characteristics or adverse selection of the exporter, such as the type of biosecurity cost they face, i.e. $\theta \in (0, 1]$. A regulator overcomes information asymmetries by structuring a contract in a manner that the exporter voluntarily reveals its true type (or value of θ), resulting in efficient biosecurity risk sharing.

$G(\theta)$ is a probability distribution of types, with $dG(\theta) = g(\theta)d\theta$. The exporter chooses a contract and the regulator spends additional resources to monitor θ and induce the exporter to behave efficiently. Moral hazard may also exist involving unknown exporter abatement actions $e(\theta) \geq 0$ towards biosecurity risk, known only to the exporter and unobserved by importing country's regulator.

An exporter's cargo has a probability of biosecurity risk (q) so abatement, $e(\theta) \geq 0$ may reduce q below its baseline level, $\bar{q} < 1$. Abatement effort is a function of θ with a constant marginal cost, such as the costs for eliminating biosecurity risk prior to shipping internationally traded goods. A regulator can offer a technical assistance grant ϕ. Costs to control biosecurity risks (q) and resulting potential damages (δ) vary among exporters. Countries are heterogeneous, i.e. biosecurity risks and efforts to deal with those risks vary among exporters. This means an ideal policy should address that variation rather than be a one-size-fits-all penalty that does not properly incentivize producers' efforts to fight biosecurity risks. Article 10 of WTO's SPS requirements

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notes that q varies among exporting countries' producers. If regulators can identify export producers by type, they can offer them unique contracts based on their type. Technical assistance ϕ is essentially a transfer from a regulator to producers of an exporting country. We capture how it varies among heterogeneous country groups by geographic region, agricultural share, and an index measuring a country's capacity for trade (*ETI*) in our empirical framework.

Our empirical model investigates how articles 9 and 10 of WTO's SPS regulations, measured in terms of levels and types of technical assistance, change trade flow volumes between exporting and importing countries. In this manner, it is possible to test whether biosecurity risk avoidance and enhanced trade flows are simultaneously achieved through SPS technical assistance investments.

Our cross-country panel model incorporates variations in timing of program implementation across countries to enable an empirical test of article 9 of WTO's SPS program, i.e. the relationship between exports and assistance. Allowing slopes to vary across country groups enables us to test article 10 of WTO's SPS program and see how these policies have a differential impact on countries in different regions.

Section 4 presents a discussion on the empirical model used to test the validity of WTO's SPS program. The dependent variable in our empirical model is export of agricultural goods receiving technical assistance. Fernandez and Sheriff (2013) suggest these exports depend on technical assistance, ϕ, (outlined in articles 9-10 of WTO's SPS requirements) as well as country-specific effects (such as presence of a border, population size, real exchange effective rate, and institutional characteristics). These fixed effects are what Carrere (2006) and Baier and Bergstrand (2007) include in a standard gravity model. We estimate a panel model with country dummies. Both papers find that regional agreements have generated a significant increase in trade between members, often at the expense of the rest of the world. The purpose of our paper is to investigate if technical assistance policies (as outlined in WTO's SPS program) have a similar impact on trade flows. Trade policy is not exogenous in Carrere (2006) and Baier and Bergstrand (2007). Following their lead, we treat technical assistance as endogenous and use a *multiple indicator solution* (MIS) to get unbiased results.

4. The Empirical Framework

4.1 Data and Variables

To evaluate Technical assistance's (ϕ) impact on trade flows as discussed in Fernandez and Sheriff (2013), we collect manually from various technical assistance reports submitted to WTO by WTO member countries data on all types of technical assistance for 1995–2013. Each country that reports technical assistance indicates the agricultural sector area of SPS focus. Such a focus may not be compartmentalized as just one type, but rather a variety involving government to government, business to business, government to business, and even business to government assistances. The information is more associated with stage of trade, and so complete information about the biosecurity may simply be undetected before trade and arrival of goods to the importing countries.

We obtain agricultural export data from a database of the *Food and Agricultural Organization* (FAO) maintained by the United Nations, and the remaining macroeconomic data from the World Bank; these data start two years before technical assistance begins and end two years after it ends. Data availability on technical assistance enables us to look at 33 countries[4] ($i = 1, 2, \ldots, 33$), from 1993 to 2015 ($t = 1, 2, \ldots, 23$). We construct an empirical model to explain how technical assistance impacts the volume of aggregate agricultural exports of goods receiving assistance

[4]Among all countries receiving assistance, only these 33 countries received technical assistance in at least three commodities for more than three years during 1993 – 2015.

Table 1. Descriptive statistics of independent variables

Variable	Units	Obs	Median	Mean	Std. Dev.	Min	Max
$AgrExport_{it}$	1,000 tons	741	62.33	891.36	1,577.06	0	9,937.09
$\left(\frac{AE}{GDP}\right)_{it}$	(%)	681	0.51	0.79	.82	0	8.1
$AgrVA_{it}$	(%)	751	12.63	15	10.84	2.09	59.95
$TAComm_{it-1}$	Number of goods	726	0	0.97	3.1	0	31
$TAduration_{it}$	Years	759	5	5.09	2.37	2	12
$ln(TAvalue)_{it}$	Current US $	759	12.13	9.91	7.89	−4.61	17.33
$\left(\frac{ManuExport}{TotExports}\right)_{it}$	%	664	29.18	33.63	23.76	1.16	99.5
Enabling Trade Index	Units	736	3.74	3.79	.44	2.8	5.12
$ln(RGDP)_{it}$	Current US $	756	8.08	7.99	1.02	5.19	9.61

($AgrExport_{it}$) (measured in thousand of tons) at any time during the period 1993–2015.[5] Our model controls for exogenous factors such as share of manufactures exports in total exports or $ManuExport_{it}/TotExport_{it}$ (in %) and per capita real gross domestic product or $RGDP_{it}$ (in 2010 US dollars). For general and overall country group statistics, please refer to information presented in Tables 1 and 2.

Aggregate agricultural exports are obtained by summing quantities of goods exported (in thousand tons) across multiple agricultural products, which receive various forms of assistance. We measure technical assistance in three ways. In one set of regressions, we sum across multiple agricultural products a binary variable, which equals 1 if the country received technical assistance from a donor country that year for a certain commodity and 0 otherwise. These commodities, which benefit from receipt of technical assistance, range from cattle meat to lemons. In this set of regressions, technical assistance or $TAComm_{it}$ (varying between 0 and 31) is the total number of commodities receiving assistance in the ith country at year t. In another set of regressions, we define technical assistance or $TAduration_{it}$ as the total number of years the ith country receives assistance in any commodity for the period 1993–2015. In the third set of regressions, technical assistance or $TAvalue_{it}$ is the total value of assistance in dollars received by the ith country for the period 1993–2015. All donor countries, with the exception of the US and EU, provide non-monetary assistance (measured by $TAComm_{it}$ or$TAduration_{it}$).[6]

Technical assistance by definition is an endogenous explanatory variable, correlated with a country's unobserved ability to trade (u_{it}), making OLS estimates from our baseline models biased. We apply the MIS to correct this bias. Other papers clearly discuss how to deal with endogenous explanatory variables in a classical regression model (see Wooldridge, 2010). The entire literature is precariously balanced on locating a proper instrument, which is correlated with the endogenous regressor, but not the error term. In practice, finding a valid instrument can be problematic. In such cases, the MIS can be a useful alternative method to deal with bias from endogenous explanatory variables.

We apply the MIS in two steps with two indicators of a country's unobserved ability(u_{it}). To capture some unobserved heterogeneity among countries receiving assistance, we will include

[5]Some countries may not have received a certain type of assistance or any assistance in some years in our sample.
[6]In our dataset USA, Canada, EU, Australia, and Japan are donor countries.

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Table 2. List of countries and commodities by geographical region

Region	Countries Receiving Assistance	Sum of $TAComm_{it}$ by region (all goods) (A)	Sum of $TAComm_{it}$ by region (intermediate goods) (B)	Sum of $TAComm_{it}$ for all regions (all goods) (C)	Share of intermediate goods among all goods receiving assistance in the region (B/A × 100%)	Share of intermediate goods among all goods receiving assistance in all regions (B/C × 100%)
East, South and Western Asia	Cambodia, China, Papua New Guinea, Philippines, Thailand, Vietnam, India, Indonesia	165	66	709	40%	9.31%
Europe and Central Asia	Armenia, Russia, Serbia, Turkey, Ukraine	57	18	709	31.57%	2.54%
Latin America and the Caribbean	Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Paraguay, Peru, Uruguay, Venezuela	347	97	709	27.95%	13.68%
Middle East and Africa	Uganda, Tanzania, Egypt, Ethiopia, Morocco, Ghana, Senegal, S. Africa	140	52	709	37.14%	7.33%

Some commodities receiving assistance are intermediate goods requiring processing before consumption; in our dataset, these are livestock, meats, cattle, chicken, hens, goats, sheep, and coffee. We present their shares in all goods receiving assistance to indicate the need for a large manufacturing sector for such goods.

in our model as the first indicator the Enabling Trade Index(ETI), which in our sample ranges between 2.8 and 5.12. This index, published by the *World Economic Forum* measures countries on their success in building a capacity for trade: covering border administration, quality of transportation services, infrastructure, technology vintage, and operating environment. The ETI is inclusive of elements to facilitate capacity and complements compliance with SPS. Including one indicator in our estimating model only changes the source of endogeneity. As a proper instrument for the first indicator ETI, we use a second indicator, a recipient country's value added by agriculture (% GDP) or $AgrVA_{it}$ from the World Bank. Both indicators measure a country's ability to trade agricultural products.[7]

4.2 Least Squares Dummy Variable Estimates

Our analysis begins with a *Least Squares Dummy Variable* (LSDV) estimation of Equation (1) with country dummies, D_c where $c = 1, 2, \ldots, 33$ and $t = 1995, 1996, \ldots, 2013$.

$$AgrExport_{it} = \beta_0 + \beta_1\left(\frac{ManuExport}{TotExport}\right)_{it} + \beta_2 ln(RGDP)_{it} + \beta_3(TA) + \beta_4(TA \times u_{it}) + \sum_{c=1}^{33}\alpha_c D_c + \varepsilon_{it}$$

$$TA = [TAComm_{it-1},\ TAduration_{it},\ TAvalue_{it}] \tag{1}$$

Traditional *Instrumental Variable* (IV) techniques consider $\beta_4(TA \times u_{it})$ a part of the population error term and find instruments for TA that are correlated with TA but not$AgrExport_{it}$. The approach of MIS is to find indicators ofu_{it}. In our paper, these are a recipient country's ETI and $AgrVA_{it}$. Both indicators reflect a recipient country's unobserved ability to export agricultural goods (u_{it}).

Wooldridge (2015) discusses this MIS in some detail for several model specifications. In our model specification endogenous technical assistance (TA) appears as an interaction term with a country's unobserved characteristics (u_{it}) or as($TA \times u_{it}$). We also assume, $(TA \times ETI) = \delta_0 + \delta_1(TA \times u_{it}) + v_1$. After some substitutions and algebraic calculations, we can replace u_{it} by ETI in Equation (1), which only changes the source of endogeneity. To get consistent estimates we need a second indicator $AgrVA_{it}$, which can be an instrument for ETI.

For the *first stage*, we estimate the residual from an OLS estimation of the endogenous ($TA \times ETI$) on exogenous variables in (1) and ($TA \times AgrVA$), and add it as an explanatory variable in the *second stage*. In the second stage estimating equation, we replace ($TA \times u_{it}$) with ($TA \times ETI$), making it appropriately exogenous. Wooldridge (2015) notes that this method generates coefficients on the endogenous and exogenous explanatory variables that are numerically identical to the *two stage least squares* (2sls) estimates. The added advantage is that the coefficient of the residual from the first stage added as an explanatory variable in the second stage gives us a heteroscedasticity robust *Hausman test* of the null hypothesis that the endogenous variable is actually exogenous. If we reject the null, i.e. if the coefficient of the residual is statistically significant, we can conclude that the endogenous variable of our model is indeed endogenous. Wooldridge (2015), Fernandez-Antolin et al. (2016) and Mariel et al. (2018) warn against using the information matrix to get standard errors of estimates. Following their suggestion, we calculate those by bootstrapping.

According to article 9 of agreement among WTO members on application of SPS measures, technical assistance may be in areas of processing technologies, research, or infrastructure. It may

[7]Recent application of this MIS are by Guevara and Polanco (2016) on public transportation choice and Mariel et al. (2018) on environmental valuation.

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take the form of advice, donations, grants, training, or equipment. The purpose of assistance is to enable countries lacking expertise to adjust to and comply with sanitary and phytosanitary measures required for trade. A member may also provide assistance when it allows a recipient country to expand market access opportunities for the product involved.[8] Data on these various forms of technical assistance come from records of various member countries reporting their investments through the WTO. Member countries such as the EU countries, US, Australia, Canada, and Japan, voluntarily report technical assistance investments by location, duration, and project targets. These records enable our empirical testing of WTO's SPS program.[9] We evaluate article 9's effectiveness by estimating a relationship between various forms of technical assistance (*TA*) and aggregate agricultural exports of goods receiving assistance ($AgrExport_{it}$) in equation (1). Readers should interpret, in a semi-log regression with $ln(TAvalue)_{it}$ as a dependent variable, if $TAvalue_{it}$ increases by1%, $AgrExports_{it}$ changes by $\frac{b}{100}$ thousand tons, if b is the coefficient of $ln(TAvalue)_{it}$. Technical assistance is a function of country characteristics, which makes this explanatory variable endogenous. To correct bias from endogenous regressors we apply the MIS. We present LSDV estimates (labeled *baseline*) and endogeneity corrected estimates (labeled MIS) in Table 4.

4.3 The Varying Coefficients Model

According to article 10 of the same agreement, while applying SPS measures, member countries are required to consider the special needs of developing countries receiving assistance. The language of article 10 specifies the importance of individual country characteristics. We propose that any impact of technical assistance by WTO members on a recipient's aggregate agricultural exports of goods receiving assistance (or $AgrExport_{it}$) will depend on the recipient country's individual as well as common country characteristics. To bring out this aspect, we divide our dataset into (j) country groups and estimate another empirical model in equation (2), where constants, as well as slopes, remain invariant over time, but vary across those j −groups.[10]

$$AgrExport_{it} = \beta_{j0} + \beta_{j1}\left(\frac{ManuExport}{TotExport}\right)_{it} + \beta_{j2}ln(RGDP)_{it} + \beta_{j3}TA + \beta_{j4}(TA \times u_{it}) + \varepsilon_{it} \tag{2}$$

In this model specification, each j– varying kth coefficient ($k = 0, 1, \ldots, 4$) can be viewed as the sum of a common mean coefficient ($\bar{\beta}_k$) and deviations from the common mean (α_{ki}). We assume these deviations from the mean,(α_{ki}), are random and follow the approach of Swamy (1970) to estimate each group-varying coefficient. These country groups are established based on two criteria for clarity: (i) an economic characteristic, the value of agricultural raw material exports as a share of *GDP* or $\frac{AE}{GDP}$ and (ii) a non-economic characteristic, geography. In (i) countries with lower than median values of $\frac{AE}{GDP}$ ($\left(\frac{AE}{GDP}\right)_{it} \leq 0.51\%$) belong to one group and the rest belong to another group ($j = 2$). In (ii), we sort and group the entire dataset into four geographical regions: *East, South, and Western Asia*; *Europe and Central Asia*; *Latin America and the Caribbean*; and *Middle East and Africa*($j = 4$). Names and composition of geographical areas follow those specified in UNDESA (2020).

Grouping the data based on both the economic characteristic of $\frac{AE}{GDP}$ and the non-economic characteristic of geography offers several empirical benefits. *Comparative analysis*: By grouping

[8]Readers should note, assistance is not a WTO mandate or bi-lateral or based on current trade relations in agricultural products. We believe this assistance will be a function of unknown country characteristics, like a recipient country's ability to trade, thus making the baseline model estimates biased.

[9]The *North American Plant Protection Organization* (NAPPO) and *The Canadian Food Inspection Agency* (CFIA) are examples of such sources.

[10]Article 9 is titled, *Technical Assistance* and title of article 10 is *Special and Differential treatment*. For details please refer to the text of the agreement.

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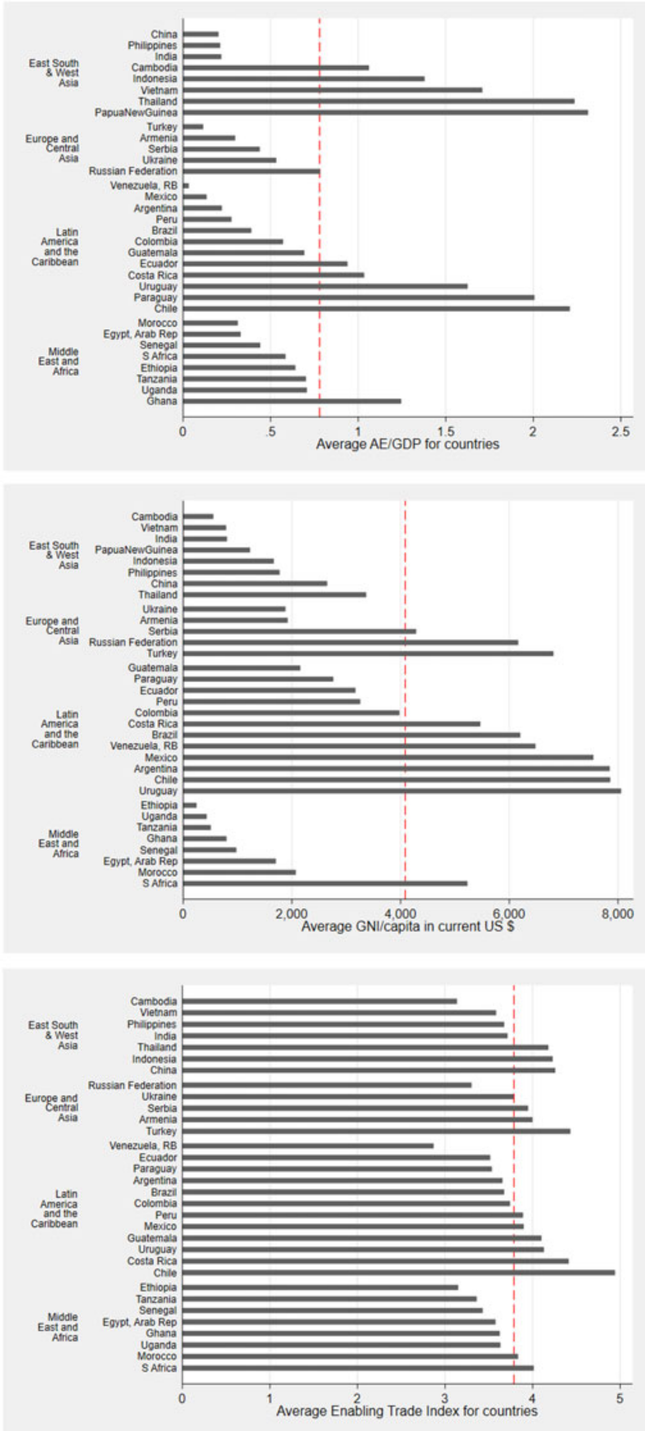

Figure 1. Time Averages of *AE*/*GDP*, *RGDP*, and *ETI*.

countries based on $\frac{AE}{GDP}$, we can compare the trade patterns of nations in terms of their agricultural raw materials exports. This allows for a comparative analysis of how different types of technical assistance contribute to agricultural exports in different country groups. Additionally, grouping

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by geography enables comparisons between regions, providing insights into regional variations in agricultural trade. *Identifying patterns and trends*: Grouping based on $\frac{AE}{GDP}$ and geography helps identify patterns and trends in agricultural exports. It allows researchers to examine if countries with high $\frac{AE}{GDP}$ ratios cluster in specific geographic regions, indicating potential regional specialization in agricultural production and trade. We can identify patterns and relationships that may exist between the size of agricultural sectors of countries (as reflected by $\frac{AE}{GDP}$) and the importance of specific kinds of technical assistances. *Policy implications*: Analyzing the data grouped by both criteria can inform policymakers about the relationship between technical assistance, agricultural exports, and geographic factors. It can help identify regions where agricultural exports play a crucial role in the economy and guide donors of technical assistance in formulating targeted policies to promote and sustain agricultural trade and economic development in those regions. *Regional cooperation and trade agreements*: Grouping countries based on geography can facilitate regional cooperation and trade agreements (Bhagwati, 1992). It allows policymakers to identify opportunities for regional trade integration and the potential for enhancing agricultural exports among neighboring countries with similar geographic characteristics.

Overall, grouping our data by the economic criterion of $\frac{AE}{GDP}$ along with the non-economic criterion of geography enhances the depth and richness of the analysis, leading to a more comprehensive understanding of the relationships between trade, biosecurity, and the specific characteristics of different countries and different regions. Figure 1 presents time averages of every country's share of agricultural raw material exports (% of GDP) or $\frac{AE}{GDP}$ along with their $\frac{GNI}{capita}$ in current US$ and Enabling Trade Index (ETI); dotted red lines indicate their averages, respectively. Agricultural sector is very relevant in those countries who fall in the above average $\frac{AE}{GDP}$ group. Here, we see almost all countries in *Europe and Central Asia* and *Middle East and Africa* are in the below average $\frac{AE}{GDP}$ group (with the exception of Ghana). The UNDESA (2020) report classifies countries based on their $\frac{GNI}{capita}$. We can measure a country's level of development along similar lines. Countries with $\frac{GNI}{capita} < 4085$ are in the *low to lower middle income countries* group and the remaining are in the *upper middle to high income countries* group. Here, we see that almost all countries in *East, West, and South Asia* and *Middle East and Africa* (except South Africa) are in the *low to lower middle income countries* group. We use the ETI to measure a country's capacity for trade. Again almost all countries in *Middle East and Africa* (except Morocco and South Africa) are in the *below average ETI* group.

To correct for endogeneity bias in this model we again apply the MIS. We present only endogeneity corrected estimates (labeled MIS) in Tables 4–9.

5. Results and Discussion

5.1 Panel Model with Country Dummies

Table 3 displays results from the estimating model in Equation (1). Columns labeled MIS in Table 3 highlight the impact of including the Enabling Trade Index (*ETI*) as an interaction term with all three forms of technical assistance ($ETI \times TA$), while correcting for endogeneity. Here *ETI* is our first indicator of a recipient country's unobserved ability to trade. Including this interaction term allows us to look at the impact of technical assistance on the export of goods receiving assistance as a function of *ETI*. Including *ETI* in our model is integral to addressing the supply chain in terms of facilitation of trade procedures, physical capacity, and communication.

The first three columns of Table 3 present estimates of the *baseline* model, which does not control for a country's capacity for trade, *ETI*. In absence of this index, our *baseline* model estimates show that no type of assistance has a positive impact on aggregate agricultural exports of goods receiving assistance($AgrExport_{it}$). These *baseline* model estimates suffer from endogeneity bias. The estimates we present below using the MIS are unbiased and give more reliable inferences.

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Table 3. Technical assistance and agricultural exports relationship

	Baseline			MIS		
	Dep Var $AgrExport_{it}$			Dep Var $AgrExport_{it}$		
	(1)	(2)	(3)	(4)	(5)	(6)
$TAComm_{it-1}$	12.65 (9.14)			−258.32 (1,709.16)		
$TAduration_{it}$		47.10 (54.02)			1513.32*** (450.05)	
$ln(TAvalue_{it})$			−46.92*** (17.1)			555.72 (563.49)
$ETI_{it} \times TAComm_{it-1}$				68.67 (435.09)		
$resid_{TAComm}$				86.29 (505.82)		
$ETI_{it} \times TAduration_{it}$					93.34 (118.68)	
$resid_{TAduration}$					150.47 (118.99)	
$ETI_{it} \times ln(TAvalue_{it})$						160.62 (144.89)
$resid_{TAvalue}$						−59.23 (146.24)
$\left(\frac{ManuExport}{TotExports}\right)_{it}$	5.62 (3.78)	5.14 (3.71)	5.14 (3.71)	4.03 (4.54)	7.00 (5.9)	0.52 (5.45)
$ln(RGDP_{it})$	961.09*** (126.25)	1008.07*** (122.64)	1004.36*** (122.64)	1048.22*** (152.6)	898.87*** (164.58)	704.5* (417.13)
cons	−8451.18*** (1,211.91)	−8926.42*** (1,243.24)	−6326.21*** (809.03)	−9392.4*** (1,344.16)	−15752.76*** (1,737.23)	−18484.18*** (3,841.37)
Observations	644	663	663	624	643	643
R^2	.83	.83	.83	.84	.83	.83

Estimates in (3) and (6) are from semi-log regressions; if $TAvalue_{it}$ increases by 1%, $AgrExport_{it}$ changes by b/100 thousand pounds (b = coefficient of$TAvalue_{it}$).
Notes: Standard errors are in parenthesis; obtained via bootstrapping for MIS models; seed = 101,016; reps = 1,000; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

To facilitate our discussion, we define three types of partial effects: (i) *diversification* $= \frac{\partial AgrExport_{it}}{\partial TAComm_{it-1}}$, (ii) *duration* $= \frac{\partial AgrExport_{it}}{\partial TAduration_{it}}$, and (iii) *value* $= \frac{\partial AgrExport_{it}}{\partial TAvalue_{it}}$. Figure 2 illustrates the relationships, estimated applying the MIS, of each partial effect as a function of the ETI, with a 90% prediction interval for a one-tail test, obtained via bootstrapping. These bias corrected partial effects are significant positive if the lower bound of a prediction interval lies above the $y = 0$ line (they are significant negative if the upper bound lies below the $y = 0$ line). Technical assistance having a positive impact on trade is the desired effect, so we focus our discussion on positive estimated partial effects. A test of article 9 leads to mixed results. $TAComm_{it-1}$ does not have a statistically significant impact on $AgrExport_{it}$ for any value of the *ETI*. Two other forms of technical assistance, $TAduration_{it}$ or $TAvalue_{it}$, have a positive significant impact on recipient countries' aggregate export of goods receiving assistance for some specific values of *ETI*.[11] Rather than offering assistance across a broader spectrum, such

[11]Partial effects $\frac{\partial AgrExport_{it}}{\partial TAComm_{it-1}}$ are not statistically significant for any *ETI*; partial effects, $\frac{\partial AgrExport_{it}}{\partial TAduration_{it}}$, are significant positive for $ETI \geq 3.88$; partial effects $\frac{\partial AgrExport_{it}}{\partial TAvalue_{it}}$ are significant positive when $ETI \geq 3.07$.

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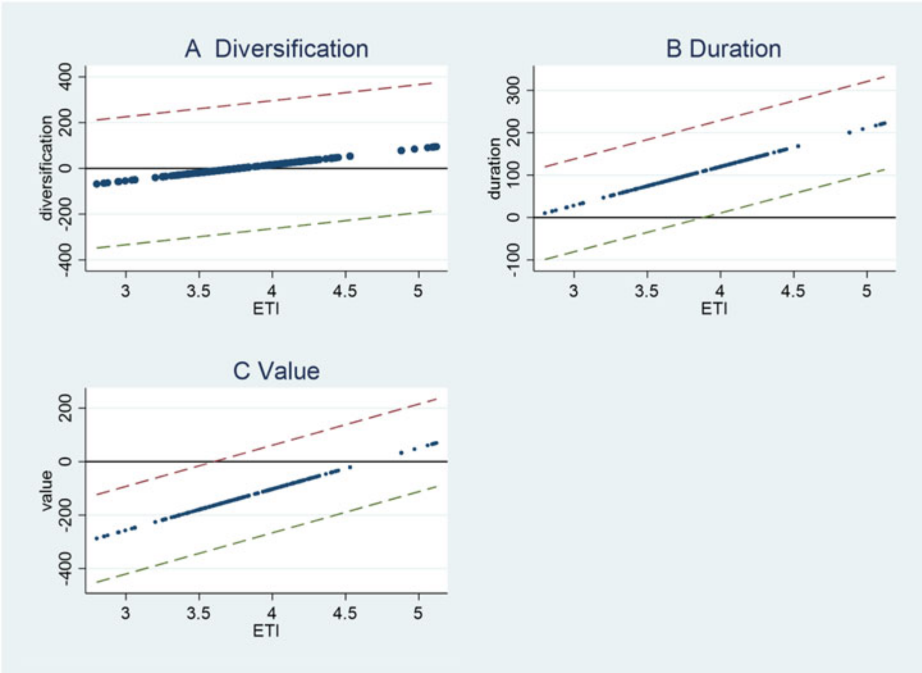

Figure 2. Partial Effect of Technical Assistance on $AgrExport_{it}$.

assistance provides support to recipient countries that are exporting agricultural products based on their comparative advantage. In subsequent sections, we explore more this differential impact of various forms of technical assistance on trade flows by characteristics of heterogeneous countries receiving it. It is relevant to consider that the array of countries, included in the dataset, offer useful variation that can illustrate why a different form of technical assistance gives different results. For example, countries vary according to potential pest issues that might affect agricultural crops. Duration ($TAduration_{it}$) and the array of crops impacted by assistance ($TAComm_{it}$) can be central to those countries, with pest issues, requiring fundamental efforts to implement lasting solutions and compliance with SPS measures.

5.2 The Random Coefficients Model: Group by AE/GDP

As mentioned previously, we sort and group our data by*AE*/*GDP*, to evaluate the role of article 10 of WTO's SPS measures on trade and biosecurity. Countries with lower than median values of *AE*/*GDP* belong to one group and the rest belong to another group. In Figure 3, we label the former below median and later above median. We will use estimates from Equation (2) to test our proposition. Controlling for a country's capacity for trade by including *ETI* as an interaction term with technical assistance ($ETI \times TA$) in (2) allows us to evaluate the impact of article 10 of the WTO's SPS Program on a recipient country's exports and also correct bias from endogenous regressors. In the interest of saving space, in Tables 4–6, we present only bias corrected estimates from Equation (2) applying the MIS.

Figure 3 illustrates *diversification* $\left(\frac{\partial TAComm_{it-1}}{\partial AgrExport_{it}}\right)$, *duration* $\left(\frac{\partial TAduration_{it}}{\partial AgrExport_{it}}\right)$, and *value* $\left(\frac{\partial ln(TAvalue_{it})}{\partial AgrExport_{it}}\right)$ as functions of the *ETI*, with a 90% prediction interval for a one-tail test. These are based on estimates applying the MIS. For *value*, the lower bound of the 90% confidence band lies above the $y = 0$ line for the below median subgroup when $ETI \leq 3.29$ and the above median subgroup when $ETI \leq 3.32$. In the same figure *diversification* is positive significant, if $ETI \geq 4.41$ in both below

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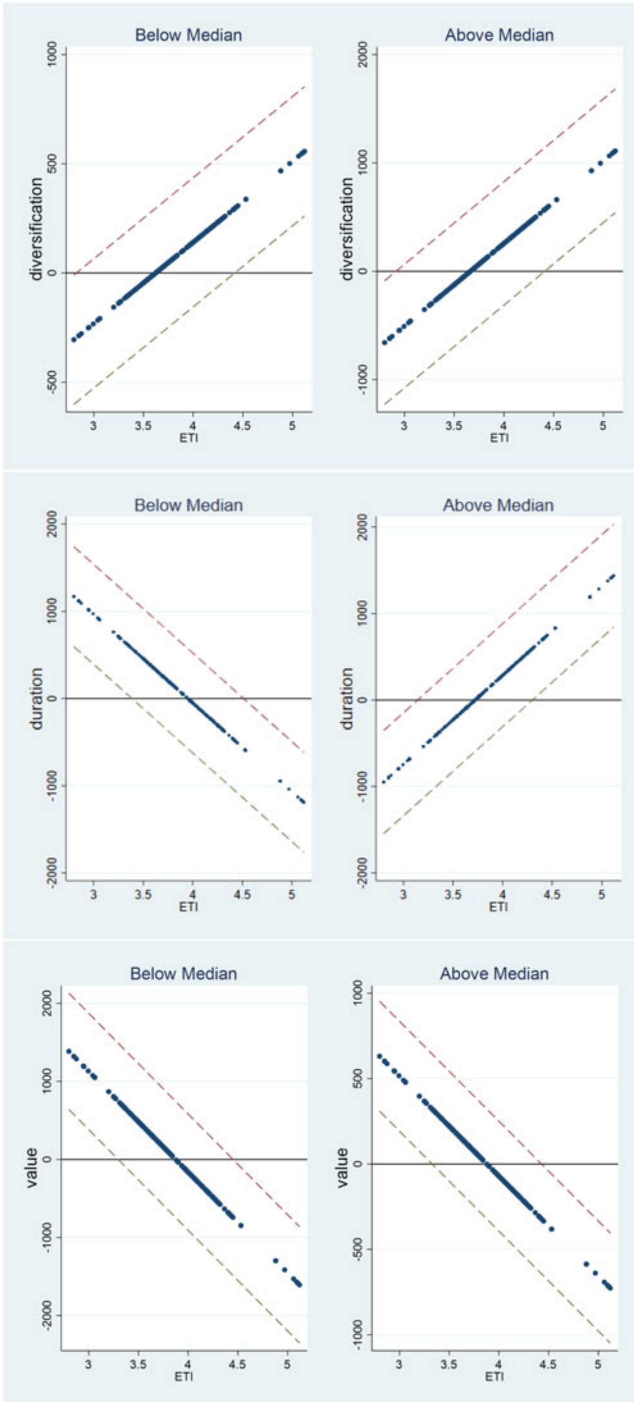

Figure 3. Partial Effect of *TA* on $AgrExport_{it}$.

and above median groups. Duration of assistance has a significant positive impact on $AgrExport_{it}$, with a narrow prediction interval, when $ETI \leq 3.89$ in the below median group or $ETI \geq 3.74$ in the above median group. *Duration* implies time devoted to solving SPS issues, such as a pest in agricultural cultivation, separate from and not in the supply chain.

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Table 4. Commodities receiving assistance and volume of aggregate agricultural exports

	MIS	
	Dep Var $AgrExport_{it}$	
	$AE/GDP_{it} < Median$	$AE/GDP_{it} > Median$
$TAComm_{it-1}$	−1,052.29	−2,833.37
	(3,892.64)	(2,700.43)
$\left(\frac{ManuExport}{TotExport}\right)_{it}$	24.12***	21.24***
	(5.36)	(4.86)
$ln(RGDP)_{it}$	577.63***	71.33
	(197.03)	(158.76)
$ETI_{it} \times TAComm_{it-1}$	297.35	773.03
	(988.82)	(700.71)
Residual	105.42	−831.15
	(1,104.34)	(752.67)
cons	−4,699.88***	−330.85***
	(0.00)	(0.00)
Observations	624	624
Groups	2	2

Notes: Reject test of parameter constancy; Standard errors are in parenthesis and obtained via bootstrapping; seed = 101,016; reps = 1,000; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 5. Duration of assistance and volume of aggregate agricultural exports

	MIS	
	Dep Var $AgrExport_{it}$	
	$AE/GDP_{it} < Median$	$AE/GDP_{it} > Median$
$TAduration_{it}$	4,016.89***	−3,830.07***
	(1,665.81)	(1,459.60)
$\left(\frac{ManuExport}{TotExport}\right)_{it}$	55.52***	−9.07
	(15.03)	(13.04)
$ln(RGDP)_{it}$	1,306.82***	−520.56**
	(337.23)	(291.96)
$ETI_{it} \times TAduration_{it-1}$	−1,016.73**	1,029.16***
	(446.25)	(387.86)
Residual	1,171.63***	−1,057.37***
	(458.98)	(393.16)
cons	−12,455.8***	5,144.79***
	(0.00)	(0.00)
Observations	643	643
Groups	2	2

Notes: Reject test of parameter constancy; Standard errors are in parenthesis and obtained via bootstrapping; seed = 101,016; reps = 1,000; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

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Table 6. Monetary assistance and volume of aggregate agricultural exports

	MIS	
	Dep Var $AgrExport_{it}$	
	$AE/GDP_{it} < Median$	$AE/GDP_{it} > Median$
$ln(TAvalue_{it})$	5,111.93***	2,608.26
	(1,648.28)	(1,807.44)
$\left(\frac{ManuExport}{TotExport}\right)_{it}$	56.52***	43.21***
	(11.04)	(12.6)
$ln(RGDP)_{it}$	4,285.49***	1,778.41
	(1,276.33)	(1,339.57)
$ETI_{it} \times ln(TAvalue_{it})$	−1,319.38***	−673.44
	(428.08)	(468.98)
Residual	1,296.51***	753.77*
	(419.21)	(457.05)
cons	−36,298.65***	−15,062.2***
	(0.00)	(0.00)
Observations	643	643
Groups	2	2

Notes: Reject test of parameter constancy; Standard errors are in parenthesis and obtained via bootstrapping; seed = 101,016; reps = 1,000; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

High capacity for trade (measured by *ETI*) is crucial for *diversification* and *duration* in the above median *AE*/*GDP* group. In this group, where a typical country would have a relatively larger agricultural sector, those with a higher *ETI* have a greater ability to diversify their agricultural exports and sustain trade relationships over time compared to countries with a lower *ETI*. Thus, they benefit more from non-monetary kinds of assistance ($TAComm_{it-1}$ and $TAduration_{it}$). This suggests that these forms of technical assistance contribute positively to the ability of countries with higher trade capacity to diversify their agricultural exports and maintain trade relationships over time.

This is not the case for monetary technical assistance ($ln(TAvalue_{it})$), which has a desired impact on trade in observations with low *ETI* values, for both groups, above and below median *AE*/*GDP*. This implies that monetary assistance can be particularly effective in improving agricultural trade outcomes for countries with limited trade capacity. This is also the case for *duration* in the below median group.

These results have important policy implications. They suggest that policymakers should prioritize efforts to enhance trade capacity, as measured by *ETI*, in order to promote agricultural trade diversification, and sustain trade relationships over time. It underscores the need for targeted technical assistance programs, specifically $TAComm_{it-1}$ and $TAduration_{it}$, to support countries with higher trade capacity in achieving these objectives. Furthermore, our results highlight the importance of considering the specific needs of countries with lower trade capacity. Providing monetary technical assistance tailored to their requirements can help boost their agricultural trade outcomes, potentially leading to increased diversification and ability to sustain trade relationships in the future. Fostering regional cooperation among countries with similar trade capacity levels could be beneficial. Collaborative efforts could focus on sharing best practices, knowledge transfer, and joint initiatives to improve trade capacity. Regional cooperation can

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also create opportunities for shared technical assistance programs, maximizing the impact and effectiveness of resources. In summary, our results emphasize the significance of trade capacity, technical assistance, and regional cooperation in agricultural trade outcomes. We underscore the need for targeted assistance to support *diversification* and *duration* in countries with higher trade capacity while recognizing the potential benefits of monetary assistance for countries with lower trade capacity. Policymakers can use these insights to shape effective strategies and initiatives to promote agricultural trade development.

Sign and significance of remaining regressors do not follow a uniform pattern across Tables 4–6. We discuss what each relationship might imply. *ManuExport* (% of*TotExport*) may have a positive impact on *AgrExport* when agriculture and manufacturing complement each other and collectively positively impact growth. This may be true in countries that export processed agricultural products that require manufacturing to do the processing. These countries would benefit more from monetary assistance. We may see the opposite, in cases where a growing agricultural sector crowds out manufacturing; here assistance in terms of number of commodities receiving assistance ($TAComm_{it-1}$) and duration of assistance ($TAduration_{it}$) may be more useful. Higher economic growth (measured by $ln(RGDP)$) may have a negative impact on *AgrExport* if structural changes move resources away from agriculture. The reverse will be true for countries where structural changes from growth move resources towards agriculture. Figure 1 can help our readers roughly understand a recipient country's group placement by illustrating time averages of AE/GDP values for every country in each region.

5.3 The Random Coefficients Model: Group by Geographical Region

To gain a deeper understanding of the impact of article 10 of the WTO's SPS measures on trade and biosecurity, we organize and categorize our complete dataset into four geographical regions: (1) *East, South, and Western Asia*, (2) *Europe and Central Asia*, (3) *Latin America and the Caribbean* and (4) *Middle East and Africa*. Table 2 discusses variations in average, standard deviation, and total number of commodities receiving assistance across these geographical areas. The number of goods benefiting from assistance (and standard deviation) is largest in the *Latin American and Caribbean* region. This number and standard deviation is lowest for countries in region of *Europe and Central Asia*.[12] All countries in *Europe and Central Asia* are in the below $\left(\frac{AE}{GDP}\right)$ group, indicating the lack of importance of Agricultural exports in this region. More diffusion of technical assistance across a large number of commodities may benefit those countries who would benefit from growth of a large number and variety of commodities. The type of assistance offered may need to be tailored according to regional locations. We will use estimates from equation (2) to test our proposition. To help further distinguish between countries in these regions, based on commodities for which they receive assistance, we classify some goods needing processing before consumption as *intermediate* goods. The lowest share of *intermediate* goods among all goods receiving assistance originates from the region of *Europe and Central Asia* and the largest from *Latin American and Caribbean* region. *Intermediate* goods, by nature of requiring more processing may create more complementarities between agriculture and manufacturing.

In the interest of saving space, in tables 7–9, we present only bias corrected estimates from equation (2) applying the MIS. Figure 4 illustrates graphs of *diversification* $\left(\frac{\partial TAComm_{it-1}}{\partial AgrExport_{it}}\right)$ as a function of *ETI*, with a 90% prediction interval for a one-tail test. Countries in *East West and South Asia* with a low $ETI \leq 3.37$ benefit most from *diversification*. In this region 40% of goods receiving assistance are *intermediate* (the largest share we can see in the second to last column of Table 2), which explains why low *ETI* may not hinder *diversification* or the positive impact of $TAComm_{it-1}$ on trade. Below average $\frac{GNI}{capita}$ does not hinder *diversification* in this region either, as all countries here are in the *low to lower-middle income countries* group (see Figure 1).

[12]Most recipient countries in this group are from the *Central Asian* region.

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Table 7. Commodities receiving assistance and volume of aggregate agricultural exports

	MIS			
	Dep Var $AgrExport_{it}$			
	East, South and Western Asia	*Europe and Central Asia*	*Latin America and the Caribbean*	*Middle East and Africa*
$TAComm_{it-1}$	36100.67***	384.45	−3456.32**	−288.67
	(12,459.06)	(10,279.26)	(1,871.29)	(524.48)
$\left(\frac{ManuExport}{TotExport}\right)_{it}$	37.22***	9.41	64.12***	−5.04***
	(12.78)	(10.5)	(5.24)	(1.86)
$ln(RGDP)_{it}$	492.83*	−446.4**	481.18***	43.01*
	(343.71)	(229.81)	(171.12)	(27.79)
$ETI_{it} \times TAComm_{it-1}$	−9237.48***	−97.71	880.00**	72.37
	(3,216.09)	(2,623.35)	(476.22)	(136.12)
Residual	9442.7***	−164.33	−613.59*	−77.6
	(3,303.16)	(2,510.44)	(451.52)	(148.28)
cons	−5230.16***	3849.41***	−4259.83***	−78.72***
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	624	624	624	624
Groups	4	4	4	4

Reject test of parameter constancy; Standard errors are in parenthesis and obtained via bootstrapping; seed = 101,016; reps = 1,000; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

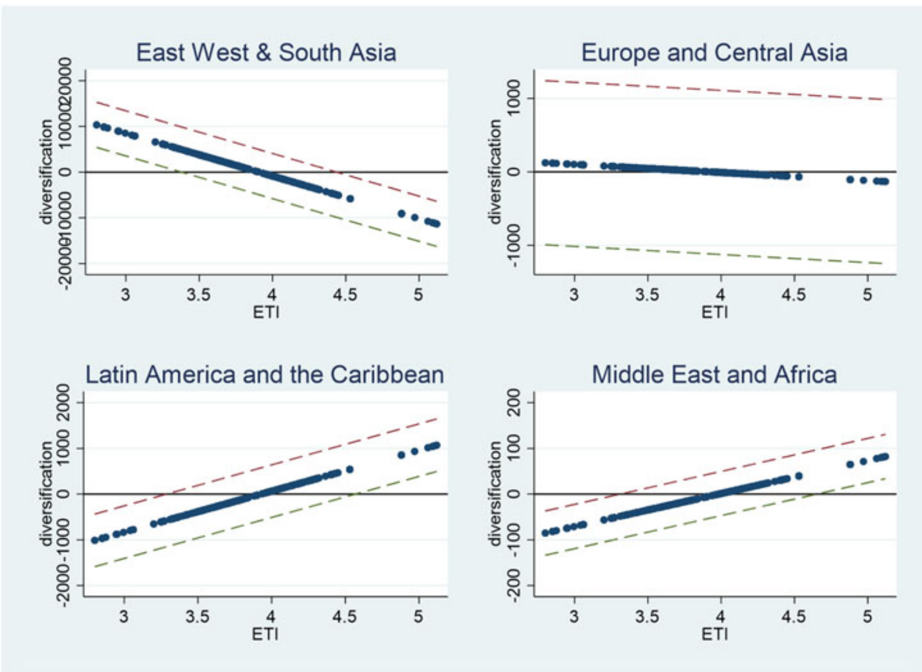

Figure 4. Partial Effect of $TAComm_{it-1}$ on $AgrExport_{it}$.

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Table 8. Duration of assistance and volume of aggregate agricultural exports

	MIS			
	Dep Var $AgrExport_{it}$			
	East, South and Western Asia	*Europe and Central Asia*	*Latin America and the Caribbean*	*Middle East and Africa*
$TAduration_{it}$	1129.32**	755.31***	−1164.55***	689.91***
	(546.2)	(291.48)	(478.37)	(122.59)
$\left(\frac{ManuExport}{TotExport}\right)_{it}$	8.05*	7.62***	60.89***	.26
	(5.48)	(2.68)	(2.53)	(1.1)
$ln(RGDP)_{it}$	521.97***	164.21***	350.50***	147.34***
	(126.03)	(29.31)	(60.63)	(25.6)
$ETI_{it} \times TAduration_{it}$	−105.93	−142.28**	303.14***	−174.43***
	(146.41)	(82.64)	(126.92)	(31)
Residual	−602.23***	137.25**	−225.00**	197.61***
	(195.02)	(77.59)	(127.01)	(34.53)
cons	−6879.87***	−2147.53***	−3043.68***	−1287.1***
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	643	643	643	643
Groups	4	4	4	4

Reject test of parameter constancy; Standard errors are in parenthesis and obtained via bootstrapping; seed = 101,016; reps = 1,000; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

In contrast, $TAComm_{it-1}$ has no statistically significant impact on trade in countries in *Europe and Central Asia*, where the share of *intermediate* goods among all goods receiving assistance in all regions is the lowest (see last column of Table 2) and all countries have below average $\frac{AE}{GDP}$ (Figure 1)). Countries in the remaining two regional groups (*Latin America and Caribbean* as well as the *Middle East and Africa*) benefit from *diversification* if they have a high $ETI \geq 4.5$. Readers should note that all countries in *Middle East and Africa* (except South Africa) are in the *low to lower-middle income countries* group.

Figure 5 illustrates how $TAduration_{it}$ impacts $AgrExport_{it}$ as a function of *ETI* and how that relationship varies across regions. Countries in *East, South, and West Asia*, who are all in the *low to lower-middle income countries* group, benefit from *duration* just as they benefit from *diversification*. $TAduration_{it}$ has a positive and significant impact on trade for all values of *ETI*. *Duration* benefits countries in the region of *Middle East and Africa*, with values of $ETI \leq 3.47$ and countries in *Europe and Central Asia* with $ETI \leq 4.56$. From the second to last column of Table 2, 37.14% of all goods receiving assistance in countries in *Middle East and Africa* are *intermediate* goods; this percentage is 31.57% for countries in *Europe and Central Asia*. All countries in both regions (except Ghana) are in the below average $\frac{AE}{GDP}$ group. With the exception of South Africa, countries in *Middle East and Africa* are in the *low to lower-middle income countries* group. These countries will benefit from longer duration of technical assistance even with low values of *ETI*. *Duration* benefits countries in *Latin American and Caribbean* with values of $ETI \geq 4.48$.

Figure 6 shows the partial impact of increasing $TAvalue_{it}$ on trade as positive and significant for all values of *ETI* in *Middle East and Africa*. For countries in *East, West, and South Asia* as well

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Table 9. Monetary assistance and volume of aggregate agricultural exports

	MIS			
	Dep Var $AgrExport_{it}$			
	East, South and Western Asia	*Europe and Central Asia*	*Latin America and the Caribbean*	*Middle East and Africa*
$ln(TAvalue)_{it}$	342.44	−211.87	1756.41***	−27.46
	(635.89)	(304.52)	(506.13)	(89.13)
$\left(\frac{ManuExport}{TotExport}\right)_{it}$	5.92	9.11***	82.79***	−2.41
	(11.21)	(3.27)	(7.67)	(2.12)
$ln(RGDP)_{it}$	0.14	−0.03	0.25***	−0.01
	(0.16)	(0.04)	(0.06)	(0.02)
$ETI_{it} \times ln(TAvalue)_{it}$	−62.94	126.27*	−453.26***	9.29
	(168.88)	(85.88)	(131.45)	(22.09)
Residual	21.06	−107.71*	502.08***	−12.3
	(196.83)	(84.51)	(134.63)	(21.98)
Cons	−478.24***	−3975.66***	−1831.29***	93.47***
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	643	643	643	643
Groups	4	4	4	4

Reject test of parameter constancy; Standard errors are in parenthesis and obtained via bootstrapping; seed = 101,016; reps = 1,000; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 10. A pseudo counterfactual test: does technical assistance affect manufactures exports?

	$ManuExport_{it}$
treatment	8.88×10^{14}
	(1.72×10^{15})
TA_{it}	-1.76×10^{15}
	(2.15×10^{15})
$AgrExport_{it}$	$1.36 \times 10^{13***}$
	(3.51×10^{12})
$ln(RGDP)_{it}$	$4.6 \times 10^{16*}$
	(2.53×10^{16})
cons	$-3.65 \times 10^{17*}$
	(2.04×10^{17})
Observations	45
R^2	0.57

Standard errors are in parenthesis ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

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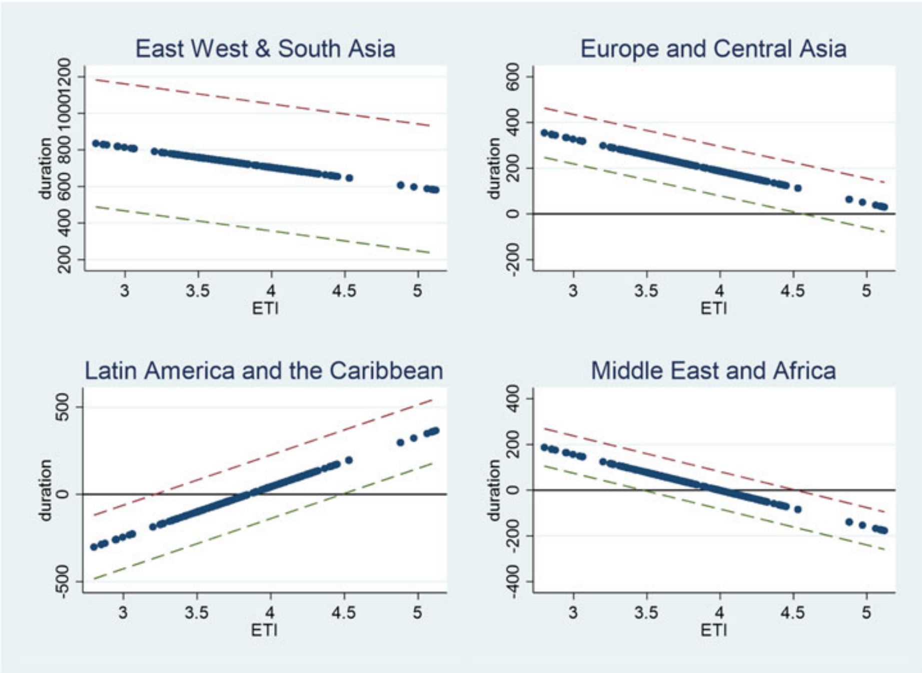

Figure 5. Partial Effect of $TAduration_{it}$ on $AgrExport_{it}$.

as *Latin America and the Caribbean*, the partial effects of $TAvalue_{it}$ on $AgrExport_{it}$ are positive for $ETI \leq 3.27$; these partial effects are positive and significant in *Europe and Central Asia* for $ETI \geq 3.73$. Monetary assistance benefits countries in *Europe and Central Asia* if these countries have a high capacity for trade. The remaining three regions benefit from monetary assistance even if they have a low capacity for trade.

Our results can provide clarity to investors for providing monetary technical assistance in countries in *Europe and Central Asia* with high *ETI*. High capacity for trade is critical in this region as all countries have below average $\frac{AE}{GDP}$ and almost a third of all goods receiving assistance are *intermediate* goods. Countries in *Latin American and Caribbean* benefit most from *diversification*, i.e. more commodities receiving assistance, and this positive impact is more for countries with higher *ETI*. Low to lower-middle income countries in *East, West,* or *South Asia* will benefit most from duration of technical assistance regardless their trading capacity (i.e., for all values of *ETI*). Even with below average $\frac{AE}{GDP}$, countries in *Middle East and Africa* benefit from monetary assistance for all values of *ETI*. From FAO (2020), it is relevant to note that the North and sub-Saharan African countries included in our dataset face high costs of trade distribution as well as post harvest production efficiency, challenges that can be ameliorated by technical assistance. Regional cooperation can play a significant role in sharing best practices and knowledge among countries with similar characteristics, such as low *ETI* values or below-average *AE*/*GDP*. Collaborative efforts can enhance the effectiveness of technical assistance programs and promote trade development in these regions.

5.4 A Pseudo Counter-Factual test

To check the robustness of our results and reliability of our inferences in previous sections, we conduct a pseudo counter factual test. We call it a pseudo test because our model is not designed as an experiment with treatment and control groups. At the same time, we want to ensure that if technical

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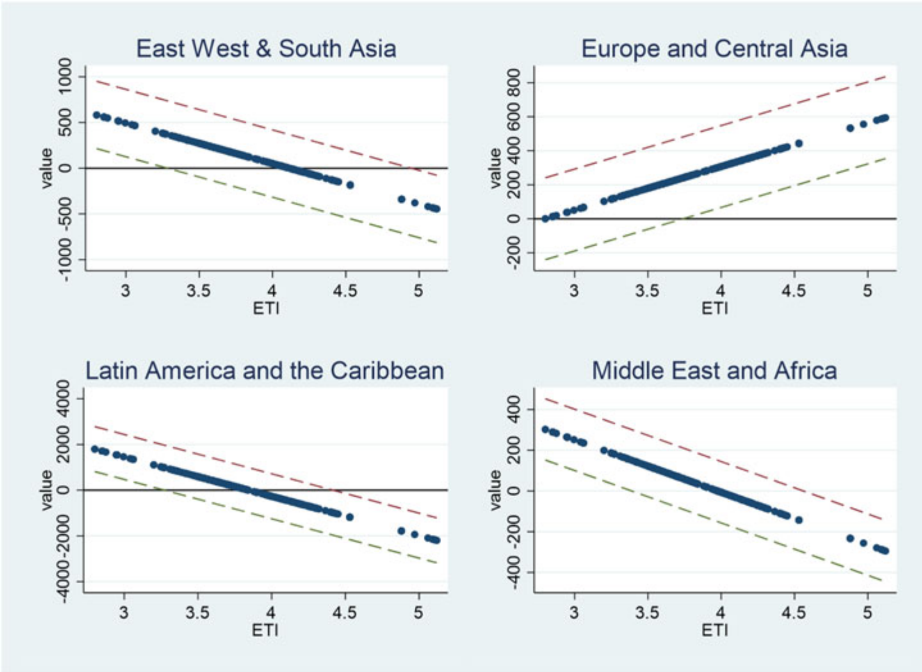

Figure 6. Partial Effect of $TAvalue_{it}$ on $AgrExport_{it}$.

assistance has an impact on trade in agricultural products, as we see in previous sections, it should not have any impact on export of manufactures (our counter-factual). To test this we only look at observations when $t = 1994$ or 1995 and create a *treatment* variable which takes the value 1 if $t = 1995$ and 0 otherwise. This variable captures the immediate impact of providing assistance, which in our dataset starts in1995. We create a second variable TA_{it} to measure the impact of technical assistance on manufactures exports; it takes the value 1 when $TAComm_{it} > 0$ and 0 otherwise. We then estimate the equation in (3) and present our results in Table 10.

$$ManuExport_{it} = \beta_0 + \beta_1 treatment + \beta_2 TA_{it} + \beta_3 AgrExport_{it} + \beta_4 ln(RGDP)_{it} + \varepsilon_{it} \quad (3)$$

Estimates from equation (3) indicate neither categorical variable, *treatment* or TA_{it}, has any statistically significant impact on export of manufactures. At the same time, *AgrExport* has a statistically significant impact on *ManuExport*.

6. Conclusion

Providing biosecurity and enhancing trade are two goals that are possible through the WTO and its SPS measures. Our econometric analysis fills a gap in the literature by testing the effectiveness of WTO's SPS regulations to address biosecurity in international trade for multiple exporters and importers of agricultural commodities.

Traditional blunt instruments such as tariffs can potentially reduce biosecurity risk by also restricting trade. Inspection of imported agricultural commodities in importing countries is imperfect and fails to detect and stop biosecurity threats that may be addressed closer to the start of the supply chain. The start is in line with the goal of articles 9 and 10 of SPS measures of the WTO, via meaningful technical assistance between exporting and importing members of the WTO.

We evaluate the impact of three measures of technical assistance, promoted by WTO's SPS measures, on agricultural trade. Under various conditions, all three forms of technical assistance prove statistically significant for enhanced trade of bio-secure agricultural goods. Countries may trade under general trade principles set forth by the Heckscher–Ohlin model by enabling trade under conditions of varied endowments and income distribution as measured by real $\frac{GNI}{capita}$ or they may enable trade with partners in similar geographic locations. We demonstrate how both trade and biosecurity are possible with technical assistance, provided to heterogeneous countries, giving them the incentive for risk abating activities.

Our analysis includes a vital interaction term of an exporting country's capacity for trade (*ETI*) that can include physical infrastructure as well as mechanisms of communication and procedures that enable trading activities. In this manner, we are able to distill the impact of technical assistance on addressing SPS. Overall, all forms of technical assistance are beneficial to a variety of countries under various circumstances that we control for. These benefits may grow with better border administration, quality of transportation services, infrastructure, technology, and operating environment (or higher *ETI*). We also distinguish the policy impact to facilitate agricultural trade in groups of countries that we identify in different ways (by geographic region, level of development or $\frac{AE}{GDP}$).

High trade capacity, as measured by *ETI*, is crucial for the effectiveness of technical assistance measured in terms of number of commodities receiving assistance and duration of assistance, in promoting agricultural trade diversification and long-term trade relationships in regions with above-median $\frac{AE}{GDP}$, while monetary technical assistance has a desired impact on trade in regions with low *ETI* values, indicating the effectiveness of monetary assistance for countries with limited trade capacity.

We also provide an appraisal of WTO's SPS measures for country groups by geography. A certain kind of assistance may benefit countries in a region, even if they have weak capacity for trade (or low *ETI*). For example, low *ETI* or below average $\frac{GNI}{capita}$ will not hinder countries in *East West or South Asia* benefiting from *diversification*, i.e. in these countries even with a low *ETI* or $\frac{GNI}{capita}$, as more commodities receive assistance, they will export more agricultural products receiving assistance (at any time in 1993 to2015). Similarly, low *ETI*, $\frac{AE}{GDP}$ or $\frac{GNI}{capita}$ will not prevent these exports from increasing in response to higher *duration* of assistance in countries of the *Middle East and Africa*, as 37.14% of commodities receiving assistance in these countries are *intermediate* goods and require time to benefit from assistance. WTO's SPS measures will not only simultaneously accomplish trade and biosecurity, based on our estimates they will also encourage donors to provide support to those countries with below average to low resources and abilities. We hope our results will give some guidance in determining allocation of limited resources by donors of technical assistance

Technical assistance is a function of a country's unobserved characteristics, which makes our treatment variable endogenous. We correct for endogeneity by applying the MIS with two indicators, a recipient country's enabling trade index (*ETI*) and value added by agriculture. Bias corrected estimates from a varying coefficients model give us marginal effects, which vary by country groups, thus allowing us to compare across those country groups, those marginal effects, i.e. the partial impact of assistance on agricultural exports of goods receiving assistance at any time during 1993 to 2015.

We find that SPS measures increase trade volume while reducing negative externalities in agricultural trade, thereby achieving WTO goals. Therefore, other stages prior to the port of entry, where inspections happen in the importing country, are pivotal for incentives in biosecurity for both importers and exporters through this program. The investment by importing countries in biosecurity risk reduction, both in the exporting countries and their own, matters significantly. A win-win situation results when such investment benefits the donors of technical assistance, the recipients, and the entire region. It is crucial to ensure that recipients with limited resources are not excluded from the program. In fact, based on our results, they should be actively encouraged to derive advantages from it. The program may create a more harmonious balance in the region.

The WTO with SPS regulations will continue to play an important and effective role in economic development for various participating countries such as those included in our analysis.

Data Availability Statement. The data and STATA codes utilized in the paper are accessible online in Fernandez and Das (2024) through the Harvard Dataverse. Should readers have any inquiries concerning the data and codes employed in this study, they should not hesitate to contact us.

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Technical Appendix

Source of Technical Assistance Data

For raw data on technical assistance, we refer to various technical assistance reports (such as G/SPS/GEN/1008 or G/SPS/GEN/2074), submitted to WTO by its member countries, available to the public on the WTO's tracking platform. Here readers can access information on SPS and technical barriers to trade, the basis of our data organized and available in Fernandez and Das (2024) in the Harvard Dataverse.

Here are the steps readers can follow to obtain data from the WTO platform.

Step 1: From the WTO members listed in Footnote 7, type in each member separately to the searchable WTO platform, along with the words SPS technical assistance. The reports the members have submitted will appear.

Step 2: Look at reports. In those reports are tables where the WTO members report SPS agricultural projects for their SPS technical assistance. There are dates and location for a SPS technical assistance agricultural project that they choose to list and identification of agricultural products (interchangeable with goods).

Creating the Technical Assistance Data

In a country-year $(i - t)$ panel data set, we create a standard dummy variable, which equals 1 if the country received technical assistance from a donor country that year for a certain agricultural commodity and 0 otherwise. $TAComm_{it}$ is the total number of commodities receiving assistance in the ith country at year-t. We provide a partial list of products (commodities) receiving technical assistance below Table 2 and a complete list (of 31 commodities) in a Technical Assistance data file available in Fernandez and Das (2024) in the Harvard Dataverse. Here we provide an Excel table with the 0,1 entries for readers to check against tables providing information on dates, locations, and agricultural products in SPS technical assistance reports provided by the WTO members as indicated by them in their listed projects. $TAduration_{it}$ as the total number of years, the ith country receives assistance in any commodity during$1993 - 2015$. $TAvalue_{it}$ is the total value of assistance in dollars received by the ith country during $1993 - 2015$ from the US or EU, also obtained from the same reports. Donor countries, Canada, Australia, and Japan provide non-monetary assistance (measured by $TAComm_{it}$ or$TAduration_{it}$).

Agricultural Exports and Macroeconomic Data

We obtain agricultural exports data from a database of *Food and Agricultural Organization* (FAO) maintained by the United Nations and remaining macroeconomic data, from the World Bank.

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