

Logistics Performance and Agricultural Exports from Developing Countries: A Gravity Model Approach.

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Executive Summary

This study examines how improvements in logistics performance affect agricultural exports from developing countries. Poor logistics performance can represent a structural trade barrier, with agricultural products being particularly sensitive to shipping delays for example. A structural gravity model helps uncover these impacts, using a panel dataset covering 121 countries from 2007-2018 alongside the World Bank's Logistics Performance Index (LPI). The primary finding shows a 1% improvement in a developing country's LPI score can be associated with a 0.36% increase in their agricultural exports, relative to domestic trade. There is also evidence of diminishing marginal returns to logistics performance and country heterogeneity, suggesting country-specific policy may be most effective. It is likely most logistics improvements in developing countries across the period were in areas with spillover effects into domestic trade. To increase this differential, more targeted focus is needed in areas specific to international trade such as customs digitalisation. However, developing countries may face several constraints, including the reliability of electricity and/or the presence of corruption. Overall, logistics performance is a fundamental driver of export growth, particularly for developing countries. The diverse impacts uncovered in existing literature and the contribution of this research reinforce the need for country-specific policy focus.

AI Statement

I acknowledge the use of generative AI in *code development* in this paper. However, the work reported remains my own.

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1. Introduction

The world of trade is becoming increasingly complex through supply chain integration and the rising use of trade policy, such as sanitary and phytosanitary measures. While countries look at alternative trade policy tools to boost exports and protect domestic industry, there are many barriers to trade, whether they be directly imposed measures (e.g. rules of origin restrictions) or naturally existing barriers such as distance. Beyond these natural barriers, logistics fits into the category of structural barriers where poor performance can severely hinder trade through shipping delays and products being held at the border due to inefficient customs processes. Therefore, logistics performance is a key determinant in a country's ability to successfully export and participate in international trade.

It is widely acknowledged that increasing trade, particularly exports, can facilitate economic growth through several channels. These include access to larger markets for exporters to boost sales and the ability to specialise, which can lead to efficiency gains. Beyond international trade, logistics improvements can also affect the domestic economy as firms often provide for both domestic and international markets. Although there is generally a strong focus on international trade, there are positive impacts on domestic trade due to shared infrastructure and supply chain linkages. These include better supply chain management, higher efficiency levels and potential productivity gains through reduced internal transport costs (Susanto, et al., 2024).

A country can underperform in terms of logistics in several areas, including inadequate infrastructure, unclear customs processes or the inability to track and trace shipments which can all hinder a firm's willingness and ability to export. Improving logistics performance can facilitate increased trade as robust systems are able to successfully handle higher volumes of shipments, making these countries a more attractive source and destination for international trade. If logistics weaknesses are ignored, moving goods from the producer to the border and beyond becomes increasingly difficult.

Developing economies rely heavily on agriculture, with the industry accounting for around 25% of value added for low-income countries in 2024.¹ Agricultural products are considerably more sensitive to logistics issues than manufactured goods where the degree of perishability plays a significant role (Moisé & Sorescu, 2021). Transit issues, lack of cold

¹ [Agriculture, forestry, and fishing, value added \(% of GDP\) - Low income](#)

storage and delays at the border significantly increase the chance of goods spoiling and being impossible to export, meaning significant resource losses for firms.

Improving key areas of logistics can help reduce this possibility and provide more stability for firms. Small firms in developing countries are likely to be disproportionately affected as they are often more involved in less technology-intensive industries such as agriculture and already do not export as much as counterparts in developed regions (World Trade Organization, 2023). Increased international trade can be a channel through which developing countries increase economic growth. The World Bank highlights the importance of logistics and acknowledges potential gains for developing countries (Wiederer, 2023). Through improved access to wider markets, better logistics performance can be a key mechanism for developing countries to boost trade and potentially move towards lifting small producers out of poverty.

There are several challenges developing countries face when it comes to improving logistics, mainly in the form of digitalisation. Many developed economies can benefit from technology regarding logistics, particularly in areas such as tracking and tracing, and customs processes. Quantifying the benefits of logistics improvements, particularly in the case of developing countries, can help inform investment decisions, to aim to boost trade and economic growth. Existing literature considers more general impacts of logistics improvements on aggregate trade flows. This paper uses a structural gravity model to provide a more nuanced approach by acknowledging the heterogeneity of impacts, answering the question of how improvements in logistics performance affect agricultural exports from developing countries where poor logistics performance is considerably restrictive.

2. Literature Review

2.1 The Gravity Model

Described as the workhorse of international trade by those such as Yotov, et al. (2016), the gravity model's first use in trade studies can be attributed to Tinbergen (1962). Tinbergen used an equivalent to Newton's law of universal gravitation², showing bilateral trade as proportional to economic size and inversely proportional to distance (Equation 1).

² Two objects are attracted by a force directly proportional to the product of their masses and inversely proportional to the squared distance between them.

Equation 1:

$$Trade_{ij} = \frac{GDP_i^x GDP_j^y}{Distance_{ij}^{2z}}$$

Equation 1 is considered a naïve gravity model, highlighting countries with larger market size that are geographically close trade more than economically smaller countries that are further apart. This early model fits well with stylised facts but fails to consider any economic theory. Anderson (1979) began to bridge the gap between the naïve work and a theoretically sound model.³

Anderson and van Wincoop (2003) built on the work of Anderson (1979). Prior to this, existing literature tended to use a ‘remoteness index’ which tried to capture how relatively close countries will trade more. These indices rarely considered theory such as Helliwell (1998) who used a GDP-weighted distance, giving small countries an extraordinarily high weighting and distorting results.

To solve this, Anderson and van Wincoop (2003) proposed both inward and outward ‘multilateral resistance terms’ (MRTs). The inward MRT captures how a country’s import demand is dependent on trade costs across all potential sources, while the outward MRT reflects how trade costs across all potential destinations affect a country’s export supply. Since MRTs are unobservable, Anderson and van Wincoop used a series of dummy variables as importer and exporter fixed effects (FE), solving the border puzzle presented by McCallum (1995).⁴ Olivero and Yotov (2012) recommended the FE become importer-year and exporter-year when using a panel dataset to account for the MRTs over time.

Before Santos Silva and Tenreyro (2006), the most common way of econometrically estimating gravity models was using an Ordinary Least Squares (OLS) log-linearised model. This introduced two main issues: heteroscedasticity biases estimates and dropping zero trade

³ Anderson (1979) showed how using a Constant Elasticity of Substitution expenditure function, and each country making a single differentiated good with fixed supply leads to a gravity-style model with solid microeconomic foundations. While this is one theoretical basis for a gravity model, there are several other possible starting points, including monopolistic competition and heterogeneous consumers/firms – see Head and Mayer (2014) for further detail.

⁴ McCallum (1995) showed trade between Canadian provinces was 20 times higher than trade between a Canadian province and a US state, with an international border. Anderson and van Wincoop (2003) showed this figure is massively overstated when using a theoretical basis. They find international borders reduce trade by 20% - 50%, a much more plausible result.

flows often excludes crucial information and reduces variation.⁵ Santos Silva and Tenreyro show trade data suffers greatly from heteroscedasticity and prove the effectiveness of a Poisson Pseudo Maximum Likelihood (PPML) estimator for use with gravity models which significantly reduces these effects and can handle zero trade flows. This paper, plus years of research and subsequent validation of the PPML estimator, shows very little point in considering an OLS gravity model. In a more recent review of their work and other gravity research since, Santos Silva and Tenreyro (2022) conclude regression results using methods other than PPML are of little benefit. However, a large proportion of existing literature continues to use log-linearised OLS specifications which raises concerns about the validity of results and comparability.

Yotov (2021) covers fifteen reasons for the use of domestic trade, highlighting how this allows for the estimation of non-discriminatory policies such as logistics performance.⁶ Yotov considers the USITC's International Trade and Production Database for Estimation (ITPD-E) as a suitable source for domestic and international trade at a reasonable level of granularity. Shepherd (2021) recommends using an international dummy variable when importing and exporting countries differ. Without domestic trade and a relevant dummy interaction, variables are collinear with necessary FE and consequently dropped from results.

The necessity of clustering standard errors (SE) is widely acknowledged to avoid understating these and correlation within. Santos Silva and Tenreyro (2022) highlight there is currently no definitive approach to clustering, but the standard procedure is to cluster by non-directional country pair – see Yotov, et al. (2016) as an example.

Weidner and Zylkin (2021) justify the use of a 3-way FE-PPML estimator (the 2-way FE shown in Anderson and van Wincoop (2003) plus a country pair FE to account for bilateral frictions) through proving it is the only PML estimator where estimates are consistent. However, they find PPML-FE specifications suffer from the Incidental Parameters Problem (IPP), producing estimates that are asymptotically biased.⁷ Weidner and Zylkin show that correcting these biases helps improve estimates and provide a Stata package (which I have translated to R for the purpose of this research, using assistance from AI).⁸

⁵ Over 50% of data points in Santos Silva and Tenreyro (2006) were dropped when the model was estimated using OLS.

⁶ Non-discriminatory policies are applied equally to all countries on a Most Favoured Nation basis.

⁷ The IPP occurs in most Pseudo-Maximum Likelihood estimators in the presence of many FE which contaminates the estimated parameters and causes bias.

⁸ Their Stata package can be found [here](#).

2.2 Logistics Performance

The World Bank describes logistics as the backbone of trade, encompassing a range of services that facilitate the movement of goods across borders and within a country.⁹ There is currently one main method to measure this: the Logistics Performance Index (LPI), published by the World Bank. This survey-based index provides a quantitative measure of how well a country performs in six key areas of logistics.¹⁰

Literature is still expanding in this area but one of the first papers to consider the impact of improving logistics performance on trade was Behar and Manners (2008). Although they used an OLS gravity model (rather than the recommended PPML specification), they found improvements in logistics performance led to gains in trade through reduced trade costs and this increase was greater when improvements were made by the exporting country rather than the importing. The gravity literature has since developed significantly, but more robust research still confirms the positive relationship.

Specific focus on the impact of logistics improvements on developing countries' trade is somewhat limited as much of the existing literature tends to consider trade facilitation and use other relevant data from the Organisation for Economic Co-operation and Development (OECD), rather than the LPI. Trade facilitation can easily be considered as a direct alternative to logistics performance given overlaps in the services under each category to improve the movement of goods. The impacts of trade facilitation improvements are heterogeneous for different income groups (Moïsé & Sorescu, 2013). Improvements led to greater reduction in trade costs for lower-middle-income countries followed by low-income countries, then upper-middle-income countries. The fact that lower income economies benefit disproportionately is perhaps more intuitive as countries may experience diminishing returns to trade facilitation. A previous study using similar methods found improvements in trade facilitation led to a smaller reduction in trade costs for developed/higher income countries (Moïsé, et al., 2011). This corroborates the theory that diminishing marginal returns to trade facilitation are present where countries approaching the frontier have fewer areas to improve, making marginal gains in trade smaller. Given the strong links between trade facilitation and logistics performance,

⁹ [The World Bank Metadata Glossary](#)

¹⁰ Customs, infrastructure, international shipments, logistics quality and competence, tracking and tracing, and timeliness.

this suggests the likelihood of diminishing returns to logistics performance also existing, albeit not yet proved in existing literature.

The theoretical link between logistics performance and agricultural trade is strong. Rodrigues Corrêa Ferreira, et al. (2021) directly use the LPI to consider the empirical relationship and find a positive impact on agricultural exports associated with improvements in logistics performance. Their descriptive analysis highlights developed countries perform better in terms of logistics performance and many poor-performing countries are in Africa, as expected. Their regression analysis follows key recommendations, using a PPML gravity model with 3-way FE. The relationship found is in line with existing literature, noting the elastic nature which suggests improvements in logistics performance indicators return a more than proportionate increase in agricultural trade.

Much of the existing literature takes a regional approach. There is a positive relationship between logistics performance and ASEAN members' trade, though the strength of the relationship varies by sector (Sy, et al., 2020).¹¹ Logistics improvements for Central Asian countries can also be associated with gains in trade (Felipe & Kumar, 2012). However, this study was published before the existence of strong guidance on the inclusion of intra-national trade in gravity modelling, meaning the LPI is collinear with FE. Felipe and Kumar used a 'remoteness index' to overcome this issue, contradicting recommendations from Anderson and van Wincoop (2003). Since the estimators used also do not include PPML, these results should be used with caution. The impact in Sub-Saharan Africa is also strong and significant with varying results among different agricultural sectors (Vardar, et al., 2025). This study acknowledges the LPI is not available annually and uses a form of interpolation to create a balanced panel for use with the generalised method of moments. Developing countries in each of the regions show varying results, with those in Africa and South America seeing the greatest trade increases following logistics improvements (Martí, et al., 2014). It is clear from existing literature that the impacts of logistics improvements on trade are heterogeneous, suggesting targeted policy could be most effective.

¹¹ Association of Southeast Asian Nations: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam.

2.3 The Research Gap

Developing countries are highly dependent on agriculture for employment and income. Agricultural exports can raise producers' income given their access to a larger market, contributing to a reduction in poverty. The ability of developing countries to participate in international trade can be hindered by several factors, including poor logistics where insufficient infrastructure, lack of storage facilities and complicated customs procedures may hamper progress. These constraints lead to increased trade costs which discourage exporters, suggesting logistics reforms could have tangible impacts.

Existing literature considers the impact of logistics performance on agricultural exports and developing countries' trade separately, but very few studies directly investigate how logistics performance impacts agricultural exports from developing countries – a notable gap given the high risk for post-harvest losses and the dependency of many developing countries on agriculture. While the gravity model is the most popular method in logistics and trade analysis, several studies do not follow most recent best practice.

This research contributes to the literature by further uncovering the heterogeneous impacts of logistics reforms using best practice from existing gravity literature. Specific sectoral and country impacts remain underexplored where aggregation bias may conceal sector-specific results. Existing literature does not combine a focus on agricultural exports and developing countries with a theoretically and econometrically sound approach to identify how logistics performance influences agricultural trading patterns – the gap this study aims to fill. This research also offers insights into the presence of diminishing marginal returns to logistics performance which can influence potential investment decisions. These decisions, if efficient, can lead to significant gains in trade and competitiveness, encouraging economic growth and supporting small producers in achieving higher and more stable income.

3. Data and Methodology

3.1 Data

To examine how exports of agricultural products from developing countries differ following improvements in logistics, data has been collated from several sources and prepared to form a final dataset.

Trade data (USITC's ITPD-E)

As discussed, it is essential to use both domestic and international trade observations when assessing the impact of non-discriminatory trade policies such as logistics performance. USITC's ITPD-E provides this information for 170 sectors and 264 countries (Larch, et al., 2025). Although this dataset unfortunately has many unknown values which are assigned zero in the raw data, there are several advantages such as not using statistical techniques to impute values and its comprehensive yearly/sectoral coverage. Yotov (2021) recommends using this data for structural gravity modelling which is becoming more popular as the need for domestic trade at a granular level increases.

Logistics Performance Index (LPI)

The Logistics Performance Index (LPI) provides numerical information for perceptions of how easy it is to transport products in the respective country (Arvis, et al., 2018). Data is given for six core subcategories with an overall score assigned which ranges from 1 to 5.¹² Information is currently available for 2007, 2010, 2012, 2014, 2016, 2018 and 2023.

However, 2023 has been removed from this research due to a methodology change, making comparability over the period difficult (Arvis, et al., 2023).

Other essential variables

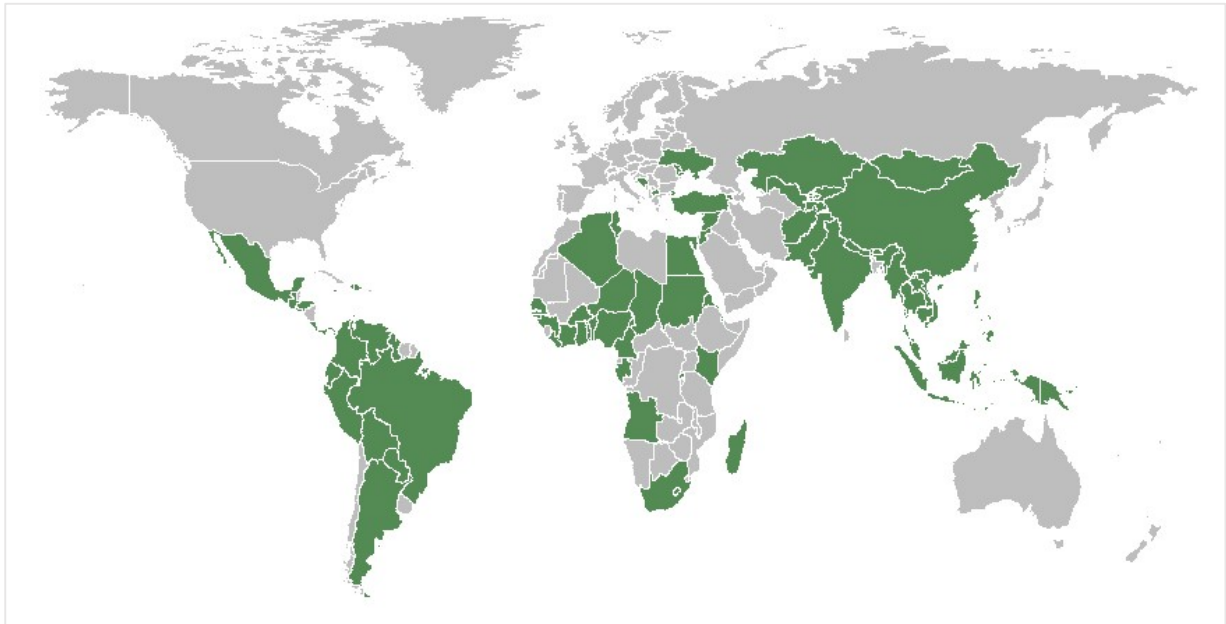
The agricultural designation, provided by the USITC, is the first 26 sectors in the ITPD-E data in this study (Larch, et al., 2025). Forestry and fishing have been excluded from the definition with the remaining ITPD-E sectors covering mining and energy, manufacturing and services.

A list of developing countries is sourced from the OECD.¹³ While a country's developing/developed status could change over time, this list is taken as fixed for the period used. Several countries listed are not considered due to a lack of LPI data. See Figure 1 for the developing country coverage.

¹² The subcategories are customs, infrastructure, international shipments, logistics quality and competence, tracking and tracing, and timeliness.

¹³ [OECD](https://www.oecd.org/).

Figure 1: Developing countries



Gravity variables

CEPII's GeoDist database provides information on static variables typically found in gravity literature (Mayer & Zignago, 2011). Those relevant here include distance, contiguity (shared border) and common language.

Mario Larch's Regional Trade Agreements Database from Egger and Larch (2008) provides excellent coverage of Regional Trade Agreements (RTAs).

Data cleaning

In the interest of transparency, there are several steps worth noting taken during the creation of the final dataset.

Although this significantly reduces the number of observations, unknown trade values were removed to reduce uncertainty as it is likely some of the unknown/zero trade flows are indeed positive. If missing values were to be associated mainly with developing economies or agricultural trade flows, this may introduce selection bias. In this case, a wide range of countries and trade flows are affected, avoiding this issue. Services sectors were also removed as logistics performance in this context and the LPI relates to goods trade.

CEPII's GeoDist database does not provide separate data for Serbia and Montenegro which are both classed as developing economies and therefore provide variation in the regression. The required data is taken from CEPII's gravity database (Conte, et al., 2022).

Several countries do not appear in each of the 6 years of published LPI data. These have been dropped from the final dataset along with countries in the ITPD-E dataset where there is no LPI information, including Free Zone data.

Given the LPI data is only available intermittently, linear interpolation has been used to create data for missing years.¹⁴ This introduces a key assumption that each country's improvements in logistics performance followed a smooth, linear trend during the missing years' data and could bias estimates towards stability if not the case. This creates two datasets: one with only published LPI data and the other with a full panel from 2007-2018.

3.2 Stylised Facts

The final coverage is 121 countries (listed in Annex A) from 2007-2018. Table 1 summarises average international exports for the 5 largest exporters in the sample over the full period. These countries differ from the largest agricultural exporters – see Table 2. Out of the largest total and agricultural exporters, only China and Brazil are considered developing.

Table 3 shows top countries whose agricultural exports account for the largest proportion of their total exports. Over 80% of the top 50 countries are all developing, highlighting their dependence on agriculture.

Table 1: Top 5 countries, total exports

Country	Avg. total exports, \$bn (share of avg. world total exports)
China	2,048 (14%)
United States	1,314 (9%)
Germany	1,245 (8%)
Japan	773 (5%)
South Korea	517 (3%)

¹⁴ 2008, 2009, 2011, 2013, 2015 and 2017.

Table 2: Top 5 countries, agricultural exports

Country	Avg. agricultural exports, \$bn (share of avg. world agricultural exports)
United States	75 (16%)
Brazil	37 (8%)
Netherlands	29 (6%)
Canada	21 (4%)
France	18 (4%)

Table 3: Top 5 countries, largest agricultural share of total exports

Country	Avg. agricultural exports, \$m (agricultural share of country's total exports)
Guinea-Bissau	177 (79%)
Comoros	33 (63%)
Kenya	2,416 (63%)
Afghanistan	390 (53%)
Djibouti	61 (52%)

The LPI also varies across the sample. Using only years with published LPI data, Table 4 summarises key metrics for both developing and developed countries. Here, it is clear developing countries perform poorly compared to developed counterparts and have significant room for improvement.

Table 4: Key LPI metrics

Metric	Developing countries	Developed countries
No. of countries	74	47
Mean	2.61	3.52
Maximum	3.54	4.13
Minimum	1.99	2.60
Standard deviation	0.33	0.41

Developed countries tend to have both higher exports and LPI scores. This positive relationship is further demonstrated when considering correlation between average exports and average LPI scores (Figure 2), using data from only the years with published LPI data. Here, developing countries' LPI scores are more highly correlated with trade than for

developed counterparts, given the difference in gradients for the lines of best fit.¹⁵ A similar pattern is also shown in Figure 3 (only using agricultural exports).¹⁶

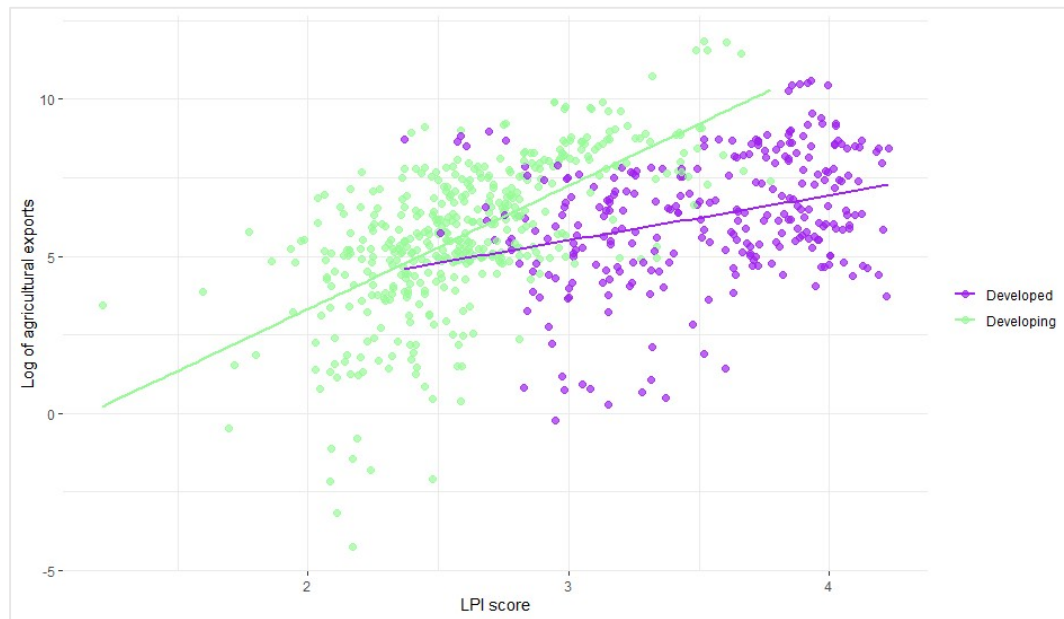
Figure 2: LPI and total exports



¹⁵ Figure 2: developed countries' gradient is 1.70; developing countries' gradient is 4.16.

¹⁶ Figure 3: developed countries' gradient is 1.44; developing countries' gradient is 3.93.

Figure 3: LPI and agricultural exports



3.3 Methodology

The structural gravity model is fundamental to further test this relationship, as demonstrated in existing literature. Following Anderson and van Wincoop (2003) and Olivero and Yotov (2012), importer-year and exporter-year FE represent the MRT along with importer-exporter FE, highlighted by Weidner and Zylkin (2021). The MRT are collinear with the GDP variables in the naïve model which means they are absorbed by the FE, eliminating potential endogeneity issues. The PPML specification provides consistent estimates under heteroscedasticity and retains zero trade flows, following Santos Silva and Tenreyro (2006). OLS results can be found in Table 5 for comparison to demonstrate this point. Common practice highlights the need for SE clustering by non-directional country pair and finally, a bias correction provided by Weidner and Zylkin (2021) is applied where possible in Table 6. Results using years with only published LPI data as well as a balanced panel are presented.

The LPI variable uses the natural logarithm (rather than the level) in line with some of the logistics literature already covered and the structural gravity theory where trade costs are multiplicative. This method also allows for the coefficient to be interpreted as an elasticity, and is consistent with the assumption of diminishing marginal returns to logistics performance, later covered in Section 5.

Equation 2 uses the PPML estimator and shows bilateral trade as a multiplicative function with a vector of typical gravity variables ($T_{ijt}\beta$ includes distance, contiguity, common language and RTA), an international dummy variable ($Intl_{ij}$), a series of relevant interaction terms and the required FE (γ_{it} , δ_{jt} and μ_{ij} reflect the exporter-year, importer-year and importer-exporter FE respectively). Equation 3 shows the equivalent log-linearised OLS model. See the full specifications in Annex B.

Equation 2:

$$X_{ijt} = \exp[T_{ijt}\beta + \beta_5 Intl_{ij} + \beta_6 Intl_landlocked_{ij} + \beta_7 Intl_agri_{ij} + \beta_8 Intl_logLPI_{ijt} + \beta_9 Intl_logLPI_dev_{ijt} + \beta_{10} Intl_logLPI_dev_agri_{ijt} + \gamma_{it} + \delta_{jt} + \mu_{ij}] \times \varepsilon_{ijt}$$

Equation 3:

$$\ln X_{ijt} = T_{ijt}\beta + \beta_5 Intl_{ij} + \beta_6 Intl_landlocked_{ij} + \beta_7 Intl_agri_{ij} + \beta_8 Intl_logLPI_{ijt} + \beta_9 Intl_logLPI_dev_{ijt} + \beta_{10} Intl_logLPI_dev_agri_{ijt} + \gamma_{it} + \delta_{jt} + \mu_{ij} + \varepsilon_{ijt}$$

Several potential interactions were dropped due to high levels of collinearity (e.g. an $Intl_dev_i$ variable for international exports from developing countries would have had a correlation coefficient of 0.98 with the $Intl_logLPI_dev_{ijt}$ variable) – see a correlogram of the final set of variables in Annex C. Without the $Intl_{ij}$ dummy interactions, several variables would be perfectly collinear with the FE and therefore impossible to estimate. Since the regression analysis focusses on exporter logistics performance, importer logistics performance is absorbed by the importer-year FE and not isolated. An RTA variable has only been included in regressions with 3-way FE to avoid potential endogeneity issues (Yotov, et al., 2016).

4. Results

4.1 Main Results

Results are shown in Table 5 where Regressions 1-4 use Equation 2 above and 5-6 follow Equation 3. Immediately, the OLS specifications appear suspect, despite using robust SE for both Regressions 5 and 6. Considering Regression 5, there is an extremely high level of significance for all coefficients, some of which are unusually large compared to existing literature.¹⁷ Regression 6 is more as expected with the additional importer-exporter FE but the

¹⁷ A range of SE were tested including cluster-robust and heteroscedasticity-robust. All variables were consistently significant at the 1% level.

large coefficient for $Intl_logLPI_dev_agri_{ijt}$ and sign of $Intl_logLPI_dev_{ijt}$ raise concern. It is also worth noting the observations dropped due to zero trade flows that OLS estimators cannot handle.

Regressions 1-4 address the issues with the OLS estimator by using a PPML specification as per Santos Silva and Tenreyro (2006). The coefficients on the typical gravity variables are generally as expected in terms of magnitude and sign, though $\ln(Dist)_{ij}$ is towards the lower bound of existing estimates.¹⁸ Gains in trade associated with having both a shared border and language are in line with existing literature, increasing trade by 65% and 49% respectively.¹⁹ The $Intl_{ij}$ dummy shows a strong bias for domestic goods trade over international trade which is similarly present with agricultural trade, possibly hinting at a large deterrence from exporting. The $Intl_logLPI_{ijt}$ is large in Regressions 1 and 3 and implies a 1% improvement in a country's LPI score is associated with gains in international trade of 6% relative to domestic trade. This magnitude may be unusually large compared to typical trade elasticities but reflects the domestic trade baseline rather than a highly questionable result. There are some insignificant results: a country being landlocked does not impact international trade relative to domestic trade and the impact of logistics improvements in developing countries does not impact international trade relative to domestic trade in Regressions 1 and 3. It is plausible that LPI improvements impact both equally as factors such as infrastructure can improve the shipment of goods domestically as well as internationally, though also possible that these coefficients are contaminated with other noise given the difference with 3-way FE. As expected, the key coefficient ($Intl_logLPI_dev_agri_{ijt}$) is positive and significant, and is stable under the various FE structures, showing a 1% improvement in a developing country's LPI score is linked to around a 0.36% increase in international agricultural trade, relative to domestic trade.

The only difference between Regressions 1 and 2 is the use of importer-exporter FE where the main affected variables are $Intl_logLPI_{ijt}$ and $Intl_logLPI_dev_{ijt}$. The FE account for factors relevant to the country pair, absorbing variables that may impact a country's LPI score such as customs provisions agreed in RTAs, leading to an insignificant result. This FE structure leads to a saturated model where much of the variation is absorbed, likely

¹⁸ This may be due to measurement methods as this analysis uses the distance between each country's most populated city. Other options include distances between capital cities or other population-weighted distances.

¹⁹ Elasticities calculated using 0.5 and 0.4 coefficients with the following formula: $(e^{\beta} - 1) \times 100$

explaining the insignificant RTA result, though including the RTA variable without these FE would lead to endogeneity issues. *Intl_logLPI_dev_{ijt}* is now significant, implying a 1% LPI improvement for developing countries increases international trade by around 4.6%, relative to domestic trade. The key coefficient hardly changes when introducing extra FE.

Regressions 3 and 4 use a full panel dataset with gaps in the LPI scores filled with simple linear interpolation for LPI variables. Distance and contiguity variables in Regression 4 should be ignored due to extremely high correlation with the FE. Overall, these results are incredibly similar to Regressions 1 and 2 respectively, even where interpolation is not used, possibly as expected as trading patterns are fairly consistent from year to year, though this may potentially downplay LPI volatility in the missing years.

Table 5: Results pre-bias correction

	(1) PPML	(2) PPML	(3) PPML	(4) PPML	(5) OLS	(6) OLS
Log(Distance)	-0.53 *** (0.04)		-0.53 *** (0.04)	2.04 (443,127)	-1.37 *** (0.03)	
Contiguity	0.50 *** (0.16)		0.51 *** (0.16)	1.72 (1,080,475)	0.71 *** (0.13)	
Common Language	0.40 *** (0.11)		0.39 *** (0.11)		0.92 *** (0.05)	
RTA		0.14 (0.10)		0.12 * (0.07)		-0.02 (0.03)
Intl	-9.54 *** (0.59)		-9.61 *** (0.57)		-13.94 *** (1.26)	
Landlocked ⁺	-0.32 (0.22)		-0.29 (0.21)		-1.68 *** (0.34)	
Agri ⁺	-3.56 *** (0.08)	-3.56 *** (0.08)	-3.55 *** (0.08)	-3.55 *** (0.08)	-4.56 *** (0.04)	-4.72 *** (0.03)
Log(LPI) ⁺	5.94 *** (0.46)	-0.56 (0.52)	6.02 *** (0.44)	0.20 (0.54)	11.83 *** (1.09)	2.80 ** (1.23)
Log(LPI) * Developing ⁺	0.11 (0.15)	4.57 *** (1.22)	0.03 (0.14)	4.03 *** (1.31)	-1.07 *** (0.30)	-3.33 ** (1.43)
Developing * Log(LPI) * Agri ⁺	0.37 ** (0.16)	0.36 ** (0.16)	0.37 ** (0.16)	0.37 ** (0.16)	2.37 *** (0.05)	2.19 *** (0.05)
No. of observations	129,914	129,531	258,970	258,730	128,487	128,101
[Pseudo] R ² for [3-way] 2-way FE	0.92	0.94	0.92	0.94	0.71	0.81
Importer-year FE	X	X	X	X	X	X
Exporter-year FE	X	X	X	X	X	X
Importer-exporter FE		X		X		X

Dependent variable is trade, measured in \$. Variables marked + have all been interacted with the Intl dummy. Specifications 1-2 and 5-6 only use years with published LPI data, Specifications 3-4 use a full panel from 2007-2018 with linear interpolation. SE are clustered by non-directional country pair, shown in parentheses. Significance levels are as follows: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.2 Bias Correction

Table 6: PPML results, bias correction

	(1b) 2-way FE		(2b) 3-way FE	
	New SE/old SE	Difference (3 d.p.)	New coefficient (new SE)/old coefficient (old SE)	Difference (3 d.p.)
Log(Distance)	0.038/0.037	<0.001	n/a	n/a
Contiguity	0.162/0.160	0.001	n/a	n/a
Common Language	0.110/0.109	0.001	n/a	n/a
RTA	n/a	n/a	n/a	n/a
Intl	0.592/0.587	0.005	n/a	n/a
Landlocked ⁺	0.220/0.218	0.002	n/a	n/a
Agri ⁺	0.083/0.082	0.001	-3.567 (0.122) / -3.564 (0.082)	-0.002 (0.040)
Log(LPI) ⁺	0.462/0.458	0.004	n/a	n/a
Log(LPI) *	0.147/0.146	0.001	n/a	n/a
Developing ⁺				
Developing *	0.161/0.160	0.001	n/a	n/a
Log(LPI) * Agri ⁺				

Notes as in Table 5. Results use coefficients/SE from Regressions 1 and 2 with the unbalanced panel.

Focussing on Regressions 1-2, Table 6 presents results using the Weidner and Zylkin (2021) bias correction. 2-way FE cause SE to be biased (columns 1-2) while 3-way FE cause both SE and coefficients to be biased. While the differences are too small to influence regression results, columns 1-2 show there is some bias which should be corrected.

Unfortunately, it is not possible to provide updated coefficients and SE for all variables in Regression 2b. This method uses a jackknife split of the data based on FE structure. Once this occurs, the variables marked n/a in Table 6 are dropped, either due to little variation or collinearity with the FE. However, Table 6 helps provide confidence that the results are not drastically affected by bias.

4.3 Robustness Checks

Several robustness checks have already been presented. Using linear interpolation and a full balanced panel makes very little difference to regression results, suggesting the extra years' data does not add much additional variation. Using this method may downplay the potential volatility of the LPI in the missing years' data, but it is unlikely the index fluctuates much

given the short intervals and consistency. Whilst including the importer-exporter FE affects some variables, the key coefficient ($Intl_logLPI_dev_agri_{ijt}$) barely changes.

To assess whether the results are driven by a small number of countries, the 3 largest developing agricultural exporters (Brazil, China and Argentina) were individually removed from the sample. The key coefficient is highly sensitive to these changes – Table 7 highlights this. Removing Argentina and smaller developing agricultural exporters shows the key coefficient converging to the 0.36 presented in Table 5, as trade flows and LPI improvements are too small to influence results.

Table 7: Key coefficient sensitivity tests using unbalanced panel

Country removed	2-way FE estimate	3-way FE estimate
None	0.365 (0.160) **	0.364 (0.159) **
Brazil	0.240 (0.153)	0.239 (0.152)
China	0.929 (0.121) ***	0.924 (0.121) ***
Brazil and China	0.366 (0.160) **	0.364 (0.159) **

The key coefficient is around 0.36 in both the full sample and when Brazil and China are simultaneously removed, suggesting the elasticity reflects the general pattern. Removing Brazil and China individually creates large fluctuations in the coefficient, implying these countries have specific characteristics that influence the coefficient in opposing directions and offset each other when grouped. China's exports grew significantly over the period, likely due to productivity and capacity growth rather than direct logistics improvements, and a larger share of Brazil's exports is much more sensitive to logistics performance. Comparing the agricultural share of total exports, as an average across the years with published LPI data, 20.6% of Brazil's exports are agricultural whilst for China it is just 0.8%. The full sample hides substantial country heterogeneity, suggesting more targeted policy approaches may be necessary rather than a one-size-fits-all response.

5. Discussion and Policy Implications

From Regression 1, LPI improvements affect international trade much more than domestic trade with the partial elasticity implying a 1% increase in LPI score is associated with a 6% increase in international trade, relative to domestic. This shows a statistically significant but unusually large result, as expected given the domestic trade baseline as the majority of the

LPI subcategories relate to international trade, with the main spillovers likely only occurring with infrastructure improvements. Although compared to a different baseline, this result provides a similar conclusion to Rodrigues Corrêa Ferreira, et al. (2021) where improvements in the LPI score lead to more than proportionate increases. However, without the importer-exporter FE in Regression 1, the LPI can act as a proxy for several variables (e.g. institutional similarity, governance), inflating the estimate. Factors such as historical relationships and institutional similarities can be positively correlated with the LPI: structurally similar countries tend to trade more and have similar LPI scores. With the importer-exporter FE, all time-invariant variation is absorbed, suggesting that improving logistics performance, on average, may not lead to the expected gains in international trade, relative to domestic trade.

The 3-way FE regression (Regression 2) shows a developing country's logistics performance affects international trade more than domestic. Once bilateral frictions are properly accounted for, the effect of improving logistics is clearly heterogeneous, as existing literature implies. Given the coefficient for the developing variable is much greater than that of the more general variable, this provides evidence of diminishing marginal returns to logistics performance where countries starting from a lower baseline may yield greater, more than proportionate gains in trade. A small improvement for a developing country produces much greater impacts than for a developed counterpart. This corroborates theoretical predictions and the expected concave relationship between trade and logistics performance. This also aligns with work from Moïsé, et al. (2011) and Moïsé and Sorescu (2013) who similarly found improvements in trade facilitation led to greater gains in trade for lower income countries.

The coefficient for agricultural exports from developing countries is positive and significant across both 2-way and 3-way FE regressions but sensitive to large agricultural exporters, demonstrating heterogeneity. The coefficient is economically meaningful as even modest improvements in logistics performance could improve international trade for developing countries, relative to domestic trade. The magnitude is perhaps smaller than expected, given theoretical predictions, but could imply most benefits to agricultural trade across the period were from improvements in logistics inputs with spillover effects such as infrastructure, reducing the relative difference. Improving transport infrastructure (e.g. road and rail infrastructure) facilitates the movement of goods both within a country from producers to consumers as well as movement from producers to the border, reducing potential time for spoilage. Improving cold storage facilities can also help reduce the chance of post-harvest

losses and the number of these globally increased throughout the period (Salin, 2018). Strategically placing these along major routes and at key border points (e.g. ports and airports) significantly improves the likelihood of products reaching consumers before spoiling.

To further contextualise this key result, the robustness tests show Brazil's agricultural exports are sensitive to changes in the LPI, and across the period (2007-2018) Brazil's LPI score increased by around 8.5%, driven by improvements in timeliness in terms of clearance and delivery, and the ability to track and trace shipments.

To increase the differential and specifically target international trade, having clearer customs processes could help reduce exporting uncertainty and moving to user-friendly digital systems could improve service quality. Although these reforms would benefit agricultural exporters, there would likely be spillovers into non-agricultural sectors as simpler border processes could encourage exports in all industries. However, there may be challenges to digitalisation due to unreliable electricity infrastructure (Wiederer, 2023), suggesting policy focus may need to be further up the infrastructure chain with developing countries primarily focussing on connectivity and establishing solid electrical infrastructure. This limitation may in part explain the small differential observed in benefits to agricultural trade. However, with targeted investment, this gap could increase as improvements in customs digitalisation benefit international trade disproportionately.

The link between logistics and corruption may also limit the possibility of developing countries increasing trade. The presence of corruption is particularly strong in developing countries (Fleming, 2019) and evidence suggests this generally hinders international trade (de Jong & Bogmans, 2011). There are several potential areas of logistics vulnerable to corruption, including customs where bribery could occur and tracking and tracing where illegal trade goes unrecorded. This implies investment in logistics reform in developing countries will need to work against systemic factors that reduce trade. Practical recommendations highlight the need for policymakers to be aware of the presence and implications of corruption in logistics and try to factor this into decisions (Acar & Kara, 2023). Although excluding a corruption variable in the specification may introduce omitted variable bias, it would be collinear with the exporter-year FE, reducing this risk. However, corruption may affect the measurement of the LPI itself (a survey-based index) as perceptions may be influenced by institutional quality.

One variable that highlights an interesting debate is $Intl_landlocked_{ij}$, being negative but statistically insignificant in Regressions 1 and 3, possibly representing limited statistical power. Theory suggests a landlocked exporting country trades less internationally due to no maritime ports and fewer border points. Over 80% of global trade moves by sea (UNCTAD, 2024). This leaves landlocked countries at a significant disadvantage, particularly landlocked developing countries which sometimes pay three times the global average in transport costs (UNCTAD, 2025). However, Table 5 results suggest this is not the case with Regressions 1 and 3 p-values being 0.15 and 0.17 respectively. Because these are greater than 0.1, the results are deemed insignificant. Yet, theory suggests they should be, highlighting a key debate between economic and statistical significance. The lack of statistical significance could be due to several factors such as reduced variation from the demanding FE structure or sample size (only 23 countries in the data are landlocked). This highlights a broader limitation of inference based solely on statistical significance. These results and a possibly arbitrary significance threshold should not lead to the dismissal of real-world impact as insignificance does not necessarily mean no effect. Other sources suggest landlocked economies are disadvantaged and this disparity is even more pronounced for developing countries, highlighting the need for targeted support for countries where structural barriers are strong.

As highlighted, the coefficients and their significance depend heavily on the model structure. Gravity models have dominated trade research for such a long time and although the key impact of logistics improvements on agricultural exports from developing countries is significant under different FE structures, it is possible a different result altogether could be obtained from a different model structure such as a time series model. The LPI itself is also limited. As a survey-based index, it relies completely on the views of multinational freight forwarders, potentially introducing some measurement errors and providing perceptions of efficiency rather than actual performance. The World Bank has recently released more data-based indicators; however, limited data currently prevents their use for panel regressions (Arvis, et al., 2026). Robustness tests suggest some stability; however, given the yearly coverage of 2007 to 2018 and the likelihood of structural changes in more recent years due to the Covid-19 pandemic and various conflicts, results may no longer apply as countries consider supply chain diversification to reduce dependence and exposure to single points of failure. One avenue for further research should include updating studies using the data-backed LPI scores once yearly coverage improves.

There are several other possibilities for further work. The results and elasticities presented are only partial elasticities but understanding economy-wide impacts of logistics reforms would be incredibly beneficial for policymakers. This could be achieved using a general equilibrium model that traces shocks (e.g. improvements in logistics performance) throughout the economy to quantify impacts such as welfare or GDP improvements. More focus should also be given to the impacts of logistics improvements on domestic trade which are not directly estimated here. Although Susanto, et al. (2024) provides a detailed review of existing literature, there is little quantitative evidence on average impacts.²⁰ There may be some data challenges to overcome but the ITPD-E dataset provides a solid basis. This additional work could be combined with Table 5 results to identify overall impacts of logistics improvements on trade – whether international or domestic.

6. Conclusion

The global agricultural industry is essential, particularly for developing economies where agriculture generally accounts for a large proportion of their exports. Increasing these could be a means of facilitating economic growth, giving exporting firms access to larger markets. Logistics reforms provide a channel through which a country can boost trade.

Evidence showing the positive impact of logistics improvements on trade is highly conclusive, though numeric estimates tend to vary. This study uses the most recent developments in gravity literature to understand the impacts. Results align with existing literature, showing the presence of diminishing returns to logistics improvements and more than proportionate increases in trade following reform. An economically meaningful result, using only years with published LPI data, shows a 0.36% increase in agricultural exports from developing countries, following a 1% improvement in the country's LPI score, relative to domestic trade. Several specific studies show the benefits of logistics reforms to domestic trade, though little work has been done to quantify these impacts more generally.

The primary contribution of this study was identifying the impact of logistics performance on agricultural exports from developing countries, acknowledging the heterogeneous effects. Agricultural products are highly perishable, meaning any delays in moving products increases the chance of post-harvest losses. Although this study provides a more nuanced approach to

²⁰ Studies in Susanto, et al. (2024) either focus on more qualitative analysis or a specific country, meaning results cannot be applied more generally.

general logistics analysis, the conclusion remains the same. Logistics reforms should be a key priority for policymakers, given the strong benefits to trade. There are several options to target agricultural exports including more/better cold storage facilities, aiming to reduce post-harvest losses. Better transport infrastructure and simplifying border processes can also benefit agricultural exports but improvements will likely have spillover effects to non-agricultural industries, benefitting trade overall.

However, potential reform in developing economies may be somewhat limited. Digitalisation of customs introduces stronger reliance on electricity, something some developing countries already struggle with. Corruption also plays a significant role in hindering gains in trade. Investing in logistics could be a simpler way to boost trade over more multifaceted trade policies such as trade agreements, potentially reducing reliance on bilateral relationships to boost trade in an increasingly complex environment. Literature is continuously expanding and this research alone has several potential extensions, including considering general equilibrium effects and more focus on domestic impacts. Existing work and this study are conclusive, showing logistics is not just a tool to support trade but a fundamental determinant in export growth, particularly for developing countries.

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Annex A – country coverage

Afghanistan	Côte d'Ivoire	Hungary	Netherlands	South Africa
Algeria	Croatia	India	New Zealand	South Korea
Angola	Cyprus	Indonesia	Niger	Spain
Argentina	Czechia	Ireland	Nigeria	Sudan
Armenia	Denmark	Italy	North Macedonia	Sweden
Australia	Djibouti	Jamaica	Norway	Switzerland
Austria	Dominican Republic	Japan	Oman	Syria
Bahrain	Ecuador	Jordan	Pakistan	Taiwan
Belgium	Egypt	Kazakhstan	Panama	Tajikistan
Benin	El Salvador	Kenya	Papua New Guinea	Thailand
Bhutan	Eritrea	Kuwait	Paraguay	Togo
Bolivia	Estonia	Kyrgyzstan	Peru	Tunisia
Bosnia & Herzegovina	Finland	Laos	Philippines	Turkey
Brazil	France	Latvia	Poland	Ukraine
Bulgaria	Gabon	Lebanon	Portugal	UAE
Burkina Faso	Germany	Liberia	Qatar	UK
Cambodia	Ghana	Lithuania	Romania	USA
Cameroon	Greece	Luxembourg	Russia	Uruguay
Canada	Guatemala	Madagascar	Rwanda	Uzbekistan
Chad	Guinea	Malaysia	Saudi Arabia	Venezuela
Chile	Guinea-Bissau	Mexico	Senegal	Vietnam
China	Guyana	Moldova	Singapore	
Colombia	Haiti	Mongolia	Slovakia	
Comoros	Honduras	Myanmar	Slovenia	
Costa Rica	Hong Kong	Nepal	Solomon Islands	

Annex B – full specifications

Equation 2:

$$X_{ijt} = \exp[\beta_1 \ln(\text{Dist})_{ij} + \beta_2 \text{Contig}_{ij} + \beta_3 \text{Com_lang}_{ij} + \beta_4 \text{RTA}_{ijt} + \beta_5 \text{Intl}_{ij} + \beta_6 \text{Intl_landlocked}_{ij} + \beta_7 \text{Intl_agri}_{ij} + \beta_8 \text{Intl_logLPI}_{ijt} + \beta_9 \text{Intl_logLPI_dev}_{ijt} + \beta_{10} \text{Intl_logLPI_dev_agri}_{ijt} + \gamma_{it} + \delta_{jt} + \mu_{ij}] \times \varepsilon_{ijt}$$

Equation 3:

$$\ln X_{ijt} = \beta_1 \ln(\text{Dist})_{ij} + \beta_2 \text{Contig}_{ij} + \beta_3 \text{Com_lang}_{ij} + \beta_4 \text{RTA}_{ijt} + \beta_5 \text{Intl}_{ij} + \beta_6 \text{Intl_landlocked}_{ij} + \beta_7 \text{Intl_agri}_{ij} + \beta_8 \text{Intl_logLPI}_{ijt} + \beta_9 \text{Intl_logLPI_dev}_{ijt} + \beta_{10} \text{Intl_logLPI_dev_agri}_{ijt} + \gamma_{it} + \delta_{jt} + \mu_{ij} + \varepsilon_{ijt}$$

Table 8: Equation key

Variable	Explanation
X_{ijt}	Trade flows (\$m) between countries i and j at time t
$\ln(\text{Dist})_{ij}$	Log of the distance between countries i and j
Contig_{ij}	Dummy variable: shared border between countries i and j
Com_lang_{ij}	Dummy variable: common ethnic language between countries i and j
RTA_{ijt}	Dummy variable: an RTA between countries i and j at time t
Intl_{ij}	Dummy variable for international trade flows
$\text{Intl_landlocked}_{ij}$	Interaction term between the international dummy and whether the exporting country is landlocked
Intl_agri_{ij}	Dummy variable for international agricultural exports
Intl_logLPI_{ijt}	Interaction term between the international dummy and exporter's LPI score
$\text{Intl_logLPI_dev}_{ijt}$	Interaction term between the international dummy, exporter's LPI score and a developing country dummy
$\text{Intl_logLPI_dev_agri}_{ijt}$	Interaction term between the international dummy, exporter's LPI score, a developing country dummy and the agricultural dummy
γ_{it}	Exporter-year FE
δ_{jt}	Importer-year FE
μ_{ij}	Importer-exporter FE
ε_{ijt}	Error term

Annex C - correlogram

