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Exploring country-level logistics infrastructure, market potential, trade exports amongst developed and emerging markets

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Background: This study critically examines the influence of national logistics infrastructure and market potential indicators and customs duty as a proxy for trade performance using an integrated measurement framework.

Objectives: The aim of this study was to compute the relative data envelopment analysis (DEA) efficiency for a set of developed and emerging market (EM) countries using widely accepted trade and logistics infrastructure components. Global logistics remains an integral component of macroeconomics when studying the potential of developed and EM growth. The study investigated the relative and relevant trade, logistics infrastructure and market potential performance.

Method: The methodological approach adopted in this study combined DEA efficiency and ordinary least squares (OLS) regressions for country-level comparisons. We incorporated trade export and import ratios for common sectors as trade performance proxies. Two important hypotheses were proposed in the study.

Results: We showed several important results. Firstly, there was clear evidence that EM countries were just as efficient as developed markets despite the scale or size differences between these country groups. Secondly, efficient countries seemed to produce better trade performance outcomes. Thirdly, relative to predicting customs duty revenues, reliable infrastructure mattered.

Conclusion: The evidence from our DEA and OLS analyses conducted suggests important relationships between logistics infrastructure, market potential and trade outcomes performance (as measured by customs duties and import and export ratios). Our data on 89 countries result in guidance for infrastructure improvement areas and linkages between market potential components and import and export ratios across key industry sectors.

Keywords: logistics infrastructure; trade import and export; global; efficiency; OLS.

Introduction

Global competitiveness and the diffusion of electronic commerce across diverse industries have extended across borders the functions of sourcing, producing and distributing products and services (Cohen & Mallik 1997; Turban et al. 2017). Distributing products across these diverse markets has become imperative for corporate profitability, but vast differences exist amongst countries in terms of transport time, international shipping risk, market access and logistics infrastructure (Arvis et al. 2010). Data from the World Bank Sustainable Development Goals (SDG) (World Bank 2017) report that significant proportions of the consumer population in emerging market (EM) countries still have limited access to reliable infrastructure and other basic services such as rail road, paved roads and communication services (McKinnon 2012; World Bank Group 2004; World Bank 2017). Kinra and Kotzab (2008) suggest that such differences are fundamental to the supplier selection, facility location and resource allocation problems in the context of macro-level supply chain decisions; and decision-makers are not willing to delay action in the hope that uncertainty in these decision areas and logistics inefficiencies (Havenga, Simpson & De Bod 2013) will abate. A better understanding of these infrastructure and trade interrelationships and persistent SDG trends may inform how decision-makers formulate strategies for managing and integrating the material, information and revenue flows across the global supply chain (Badenhorst-Weiss, Maurer & Brevis-Landsberg 2013).

Academic attention to EMs in the context of trade, logistics and market potential dependency has not kept pace in the face of the trends cited above in international expansion or growth (Quinn & Hilmer 1994; Tatoglu et al. 2016). Whilst researchers do not agree on the extent to which environmental, economic and supply chain infrastructure-related factors impact trade, there is little doubt that trade is influenced by transport infrastructure (Puertas, Martí & García 2014) through its extensive impact on efficiency (Gorman 2006; Takele & Buvik 2019). Recently, there has been renewed interest in advancing the understanding regarding the role of logistics or supply chain infrastructure indicators in environmental and economic context (Esfahbodi, Zhang & Watson 2016; Subramanian & Gunasekaran 2015).

The perspectives outlined above have at least two common threads: (1) given the expanding complexities of macro-level global supply chains and trade, lowering unit sourcing and manufacturing costs do not necessarily translate directly into lower total landed costs per unit (e.g. the total per unit costs associated with importing, exporting, transportation, customs clearance and processing of goods from distant markets) and (2) consumer and industrial demand create exports and import trade flows (and the logistical connections) between countries to fill the shortfall in domestic production and supply. However, the increased trade flow volume can itself directly affect supply chain costs, increase uncertainty, increase congestion and lessen the efficiency of logistics infrastructure, trade exports and imports and market potential (Kwon & Beom 2012; Puertas et al. 2014; Takele & Buvik 2019) for both EMs and developed markets (DMs). A data set comprising 89 countries that represented both groups of countries was developed for this study.

Uncertainty affects managing and integrating the material, information and revenue flows across the international supply chain. Efficiency differences derive from disparate infrastructure endowments and regional diversity across countries (Hausman, Lee & Subramanian 2005; Takele & Buvik 2019). Several studies (Bowe 2006; Havenga et al. 2013; Tirschwell 2007) have observed that domestic and global conditions promoting trade and commerce are clashing with obsolete infrastructure and uncertain market potential. We infer that patterns of trade development in EMs are influenced in part by (1) macro-level (rather than firm-level) logistics infrastructure, (2) the efficiency of such infrastructure and (3) other market potential factors. Therefore, research should include factors related to public infrastructure and country market potential for both EMs and DMs.

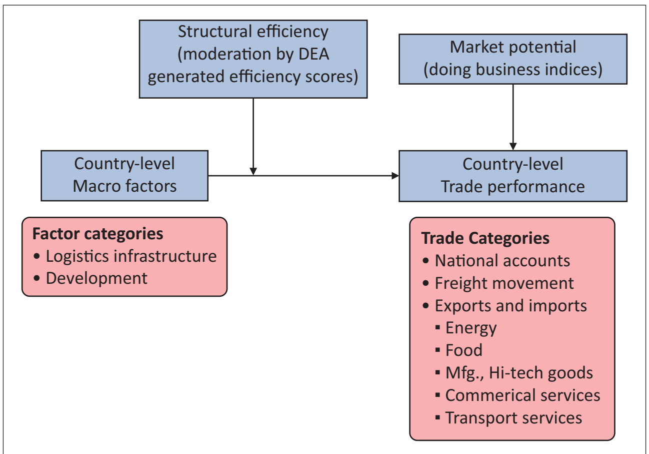
This study intended to explore logistics infrastructure, logistics efficiency, market potential and trade performance at the country level for a set of 89 EM and DM countries. We studied whether high market potential and efficient macro-level supply chain infrastructure lead to better trade performance. The objective was to analyse the causal relationships, if any, amongst logistics capability dimensions, market potential and trade in the context of logistics efficiency estimations carried out at the country level. Based upon reviews of the market clustering literature (which focuses on market potential) and logistics expenditure or infrastructure literature, some guiding premises are developed for this study. Efficiency is viewed as moderating key relationships between logistics and trade performance.

Literature background

Two diverse but content-related streams of earlier work provided the foundation for the current research on market potential and logistics infrastructure. The first stream of work adopted the country-clustering lens and assessed market potential. Some clustering methods (Cavusgil, Kiyak & Yeniyurt 2004) and the market potential weighted-indexing methods were used by Cavusgil (1997) to develop macro-level insights to EMs. Despite strengths, there are several shortcomings of the clustering approach. These include the exclusive reliance on (1) marketing indicators (Papadopoulos & Denis 1988) and environmental macro-factors (Luqmani, Yavas & Quraeshi 1994) and (2) secondary market-oriented data (Papadopoulos & Denis 1988). Whilst indexing provides the potential for grouping countries, it is generally silent on productivity or efficiency differences between groups or members of the groups. These shortcomings provide, in subsequent sections, our motivation for proposing two ordinary least squares (OLS) regression models to incorporate efficiency considerations. Given the proliferation of new data and collection methods by governments and non-governmental organisations (NGOs), EM research remains of interest to NGOs and academics alike (Bagai & Wilson 2006; Takele & Buvik 2019). We performed relative comparisons of EM and DM countries to improve generalisability.

The second stream of work on foreign markets adopted the supply chain infrastructure lens (Bowersox 1992; Bowersox & Calantone 1998; Bowersox, Calantone & Rodrigues 2003; Rodrigues, Bowersox & Calantone 2005). Heskett, Glaskowsky and Ivie (1973) first developed a methodology for estimating country-level logistics cost, applying it to the United States of America. Total logistics cost was defined as the sum of four activities: transportation, inventory, warehousing and order processing. Annual US logistics estimates appear in the State of Logistics Report published annually for over 30 years (Wilson 2006). One major challenge in estimating global logistics and supply chain expenditure is that the data required for direct measurement are not available consistently for developed nations and generally not available for emerging and transitioning countries (Bagai & Wilson 2006). Primary and secondary data must be matched in country-level analyses, but the availability of such data often varies extensively according to country and/or region of the world. The first study of global logistics expenditure by Bowersox (1992) estimated global logistics costs based on four components: total gross domestic product (GDP), government sector product, industrial sector product and total trade ratio. Follow-up studies (Bowersox & Calantone 1998; Bowersox et al. 2003; Bowersox, Closs & Stank 1999; Rodrigues et al. 2005) refined the estimation method by using an Artificial Neural Network model or by including supply chain infrastructure variables related to cost and information or communication systems. Their estimates suggest that global logistics expenditures are 13.8% of the world GDP. Interestingly, they found that logistics efficiency increased in DMs but not in the rest of the world.

Given the literature above, it is worthwhile to incorporate comparisons with data from EM countries included. Such is our proposal in this study, that is, the stream of logistics work above highlights the necessity for logistics and supply chain infrastructure investment and efficiency improvements throughout developing nations. However, it is silent on other institutional considerations, such as customs duties and national account remittances as global trade proxies, for example. It is also silent on exploring the linkage to market potential and then comparing DMs and EMs. These gaps, which our research attempts to address, limit implications for improving trade flows and country-specific logistics infrastructure. In many African EMs, access to rural consumers both grows markets and increases logistics and supply chain complexity and cost (Savage et al. 2014). Clearly, as Clark (2003) and Lorentz et al. (2015) suggest, there is a relationship between supply chain-related infrastructure and costs and the capacity of a country to attract international trade and participate in the global economy. The current research explores more explicit dimensions of macro-level logistics infrastructure along with market potential information (Gorman 2006; Orozco 2010). An integrated conceptual framework (see Figure 1) that bridges the market clustering or ranking literature and the logistics cost or infrastructure literature is proposed in Research methods and design section. This framework proposes performance relationships between the macro input factors and the country-level trade output performance dimensions and addresses two key questions:



DEA, Data envelopment analysis; Mfg, manufacturing.

FIGURE 1: Conceptual model – The roles of logistics, efficiency and market potential in determining trade performance.

- What impacts do market potential indicators (MPIs), structural efficiencies and infrastructure have on trade activity performance such as customs duty, export and import ratios at the country level?
- What insights can be offered as updates to the various findings related to trade performance and logistics infrastructure?

This kind of integrative work began widely appearing in the early 2000s (Kinra & Kotzab 2008) and continues to be of research interest today (Havenga et al. 2013). Whilst there has been some early academic interest in this area (Berman 2007; Boarnet 1997; Garrison & Souleyrette 1996; Haas, Murphy & Lancioni 2003; Ross 2002), there are no other published studies on market potential and logistics infrastructure adopted here and amongst both EM and DM countries. We compare such a set of 89 countries using the data envelopment analysis (DEA) efficiency lens and develop OLS regressions to explore the dependencies between trade factors (as dependent variables) and logistics infrastructure (independent variables). Together, these represent our primary and secondary objectives in this study, which are further detailed in subsequent sections.

Data envelopment analysis

The linear programming technique used to compute the efficiency indices is known as DEA, which was developed by Charnes, Cooper and Rhodes (1978). Since its introduction, the literature on DEA has proliferated rapidly, with a growing number of logistics-related problem contexts appearing in the literature (Cooper, Seiford & Tone 2001; Cullinane, Song & Gray 2002; Cullinane et al. 2006; Goedhals-Gerber 2016; Ross et al. 2012). Further details on DEA can be found in Cooper et al. (2001). An efficiency score of 1.0 indicates, in relative terms, which countries most effectively use their resource endowments. A score below 1.0 indicates relative ineffectiveness.

Data envelopment analysis is a non-parametric method (no arbitrary assumption of a functional form between the variables is necessary) that is especially suitable for analysis of firm-level and/or country-level problem domains that are characterised by multiple resources and activities. Before the DEA problem is solved, the orientation of the formulation is specified, that is, how much the inputs can be reduced whilst maintaining the same level of output. The former case is called input orientation and the latter one is called output orientation. Given the strategic nature of macro investments and our interest in the performance of fixed logistics capital dimensions, output orientation was selected.

Current uses of DEA aim to define a frontier envelopment surface for all observations in a sample. The frontier illustrates all efficient firms or countries in the data set, whilst those not on the frontier are inefficient. There exist *a priori* reasons to assume that, for the variables used in the current study, the countries are subject to variable returns to scale because of the heterogeneity in government policies implemented and the seemingly vast differences in foreign direct investment, GDP, logistical infrastructure and other macro-economic differences. The variable returns model creates a frontier using the convex hull and thus provides efficiency scores that are bounded from below by those of the constant returns model. Moreover, the variable returns model ensures that inefficient countries are compared only with role model-type efficient countries when computing efficiency scores and constructing the efficient frontier. In this context, both EM and DM may be efficient or inefficient in the DEA sense.

Research methods and design

The conceptual model in Figure 1 forms the basis for our methodological approach to analysing the EMs and then exploring structural differences with DMs used in the data set. As a result, EMs and developed countries alike can be efficient or inefficient based upon the unique DEA score that is computed. Thus, our novel approach fairly evaluates and compares countries on a relatively level basis given our recourse to DEA. Two research hypotheses, corresponding to two equation templates, are proposed.

We propose that there is a direct relationship to trade performance from country macro factors concerning logistics infrastructure and development (Kinra & Kotzab 2008; Weber & Weber 2004). This is our baseline proposal.

Hypothesis 1 (H1): Macro input factors focusing on logistics infrastructure and development are related to trade performance.

More specifically, H1a– H1g concern the following trade-related dependent variables:

- H1a: Customs duty received (Cduty)
- H1b: Airfreight ton-kms (Airfrt)
- H1c: Transportation services (Trnsptsvc)
- H1d: Commercial services ratio (Servratio)
- H1e: Hi-technology exports ratio (Hitechratio)
- H1f: Food exports versus imports ratio (Foodratio)
- H1g: Fuel exports versus imports Ratio (Fuelratio*)*

All variables in the model are defined in Table 1. Thus, seven linear models of the direct relationships between country-level infrastructure dimensions and trade performance factors will be estimated. Each of these seven serves as a dependent variable in Equation 1 to test Hypothesis 1, as illustrated for *H1a: Customs duty (Cduty)*:

$$CDuty_j = \beta_0 + \beta_1 {*}Remit_j + \beta_2 {*}RurlDens_j + \beta_3 {*}RoadDens_j + \beta_4 {*}RailDens_j + \beta_5 {*}Lnxdys_j + \beta_6 {*}Telemobl_j + \varepsilon_j \quad \text{[Eqn 1]}$$

In Equation 1, there are six *independent variables* (Table 1). Workers' remittances (Remit), as defined by the International Monetary Fund (IMF), is the transfer of disposable income mainly from foreign nationals and migrant workers in developed countries to family members in their home countries. The IMF views such financial transfers as drivers of consumption in the receiving country (Orozco 2010) because recipients spend domestically more than 60% of remittances on consumer goods and services. Rural density (*RurlDens*), road density (*RoadDens*) and rail density (*RailDens*) capture the concentrations of potential consumers, road infrastructure and rail infrastructure, respectively. *Lnxdys* is the natural log of average export clearance time for containers, whilst *Telemobl* captures the concentration of cell phone and landline usage. These are used as indicators of logistics infrastructure capability.

TABLE 1: Definition of variables.

Variable	Category	Measurement description	Role in the models
Cduty	National accounts	Customs and other import duties as % total tax revenue	Eqs. 1 & 2, Hla & H2a, dependent variable
Airfrt	Trade	Air freight shipments in million tons per km	Eqs. 1 & 2, Hlb & H2b, dependent variable
Trnspsvc	Trade	Ratio of export vs. import related transportation as % of commercial services	Eqs. 1 & 2, Hlc & H2c, dependent variable
Servratio	Trade	Ratio of exports vs. imports in current (2004) US$	Eqs. 1 & 2, Hid & H2d, dependent variable
Hitechratio	Trade	High-tech exports as a % of manufacturing exports	Eqs. 1 & 2, Hle & H2e, dependent variable
Foodratio	Trade	Ratio of food exports to imports as % of merchandise exports (imports)	Eqs. 1 & 2, Hlf & H2f, dependent variable
Fuelratio	Trade	Ratio of fuel exports to imports as % merchandise exports (imports)	Eqs. 1 & 2, Hlg & H2g, dependent variable
Remit	Development	Workers' remittances as % of GDP	Eqs. 1 & 2, independent variable
RurlDens	Logistics infrastructure	Rural population per sq. km of arable land	Eqs. 1 & 2, independent variable
RoadDens	Logistics infrastructure	Kms. of roadways per 1000 sq-km	Eqs. 1 & 2, independent variable
RailDens	Logistics infrastructure	Kms. of usable rail per 1000 people	Eqs. 1 & 2, independent variable
Lnxdys	Logistics infrastructure	Natural log of the average time (days) to export a standard shipping container	Eqs. 1 & 2, independent variable
Telemobl	Logistics infrastructure	Number of main line and mobile phone subscribers per 1000 people	Eqs. 1 & 2, independent variable
DEA*{-}	Efficiency	DEA efficiency score X each of the indp. variables	Eq. 2, moderation effects analysis
Crisk	Doing business	Country risk indicator	Eq. 2, indp. control
Mktsz	Doing business	Market size indicator	Eq. 2, indp. control
MktGrth	Doing business	Market growth indicator	Eq. 2, indp. control
MktRecpt	Doing business	Market receptivity indicator	Eq. 2, indp. control
Mktlnten	Doing business	Market intensity indicator	Eq. 2, indp. control
MktStruc	Doing business	Market structure indicator	Eq. 2, indp. control

Note: The asterisk (*) denotes multiplication.

H, Hypothesis; DEA, data envelopment analysis; Eq., equation; Eqs., equations; indp., independent; Cduty, customs and other import duties as percentage of total tax revenue; AirFrt, air freight shipments in million tons per kilometer; TrnspSvc, ratio of export versus import related transportation as percentage of commercial services; Servratio, ratio of exports versus imports in current (2004) U.S. dollars; Telemobl, number of main line and mobile phone subscribers per 1000 people; Lnxdys, natural log of the average time (days) to export a standard shipping container; RailDens, kilometers of usable rail per 1000 people; RoadDens, kilometers of roadways per 1000 square-kilometer; RurlDens, rural population per square-kilometer of arable land; Remit, workers' remittances as percentage of GDP; Hitech ratio, high-tech exports as a percentage of manufacturing exports; Fuelratio, ratio of fuel exports to imports as percentage of merchandise exports; Foodratio, ratio of food exports to imports as percentage of merchandise exports; Crisk, country risk; Mktsz, market size; MktGrth, market growth; MktRecpt, market receptivity; MktInten, market intensity; MktStruc, market structure; DEA, Data Envelopment Analysis Efficiency Score.

H1: Equation 1 can be extended to include structural efficiency and market potential. We propose that structural differences between developed and EM countries could be reflected in the *relative efficiency with which country input resources are combined* to generate trade activity through various logistics infrastructure capabilities. These differences impact the proposed direct relationships in H1. Countries consume different levels of the macro input factors considered earlier, but EMs have their own unique, diverse constraints (Tatoglu et al. 2016; World Bank 2017). For example, some are very mountainous and have little in the way of navigable road networks to reach rural markets, whilst others have very limited railroad or communications infrastructure (Savage et al. 2014). This results in varying reliance on available modes of distribution from country to country. Therefore, we propose that there are differences in trade performance because of structural differences in efficiency and market potential. Thus, our second research hypothesis is formulated.

H2: There are structural differences in efficiency and differences in market potential between countries that cause variance in trade performance (in addition to the logistics infrastructure and development factors included in H1).

This results in H2a–H2g for the same trade performance dependent variables as before:

- H2a: Customs duty received (Cduty)
- H2b: Airfreight ton-kms (airfrt)
- H2c: Transportation services (Trnsptsvc)
- H2d: Commercial services ratio (Servratio)
- H2e: Hi-technology exports ratio (Hitechratio)
- H2f: Food exports versus imports ratio (Foodratio)
- H2g: Fuel exports versus imports ratio (Fuelratio)

A linear model is proposed regarding the relationship amongst country-level macro factors, MPIs and the extent of moderation by efficiency. Moderation is modelled by the interaction of DEA efficiency scores with each of the six independent variables in Equation 1; MPIs, representing independent control variables, are added to Equation 1 as main effects. Thus, Equation 2, illustrated for customs duties (*CDuty*), has the following terms (Table 1):

$$CDuty_j = \beta_0 + \beta_1 *Remit_j + \beta_2 *RurlDens_j + \beta_3 *RoadDens_j + \beta_4 *RailDens_j + \beta_5 *LNxDys_j + \beta_6 *Telemobl_j + \beta_7 *DEA_j *Remit_j + \beta_8 *DEA_j *RurlDens_j + \beta_9 *DEA_j *RoadDens_j + \beta_{10} *DEA_j *RailDens_j + \beta_{11} *DEA_j *LNxDys_j + \beta_{12} *DEA_j *Telemobl_j + \beta_{13} *CRisk_j + \beta_{14} *Mktsz_j + \beta_{15} *MktGrth_j + \beta_{16} *MktRecpt_j + \beta_{17} *MktInten_j + \beta_{18} *Mktstruc + \varepsilon_j \quad \text{[Eqn 2]}$$

There are six logistics infrastructure and development dimensions ($\beta_1 - \beta_6$), the same six as in Equation 1; six corresponding *efficiency* interaction effects DEA*{β_7 $*DEA_j *Remit_j + \beta_8 *DEA_j *RurlDens_j + \beta_9 *DEA_j *RoadDens_j + \beta_{10} *DEA_j *RailDens_j + \beta_{11} *DEA_j *LNxDys_j + \beta_{12} *DEA_j *Telemobl_j$} ($\beta_7 - \beta_{12}$); and six MPIs ($\beta_{13} - \beta_{18}$). For the efficiency interaction effects, a measure of *relative efficiency* was calculated using DEA for each country, based on the macro factors and trade performance factors as input. A country is inefficient if its score is less than 1.0; scores are between 0.00 and 1.00. A country is classified as *efficient* and it is on the efficient frontier if its score is 1.0; this implies that it is not possible to increase any of its outputs without increasing any of the inputs (or, alternately, it is not possible to decrease any inputs without decreasing some outputs). For inefficient countries, the higher the DEA score, the closer that country is to the efficient frontier. Finally, the six MPIs in Equation 2 include *country risk (Crisk), market size (Mktsz), market growth (MktGrth), market receptivity (MktRecpt), market intensity (MktInten) and market structure (MktStruc)*.

Research data

Quantifying foreign market opportunity is a primary concern for academics, practitioners and policymakers, and a diverse set of approaches has been reported (Helsen, Jedidi & DeSarbo 1993; Rodrigues et al. 2005). In this study, macro-level trade proxies are used to represent the countries' economic perspectives. We operationalise many of the construct dimensions reported in Kinra and Kotzab's (2008) conceptual framework for exploring logistics and supply chain macro-level system complexity. The data were categorised as either inputs (independent variables) or outputs (dependent variables) (Table 1). The seven dimensions of country-level trade performance indicators were considered outputs (e.g. air freight, hi-technology exports ratio, food or fuel exports ratio and customs duty). Both models' input dimensions include logistics infrastructure (e.g. rail density and road density); Equation 2 also has Market Potential Indicators (MPI) ('Doing Business Indicators'). The Center for International Business Education and Research (CIBER) at Michigan State University, East Lansing, MI (MSU-CIBER) publishes an annual ranking of EMs (http://globaledge.msu.edu**)**. There are eight MPI factors including country risk, market size, market growth, market receptivity, market intensity, market structure, market infrastructure and market consumption capacity. The first six of these eight dimensions were selected for use in this study to represent the market potential input dimensions in Equation 2. We used matched data collected from another secondary source in the place of market infrastructure and market consumption capacity so that 'trade' and 'logistics infrastructure' details could be calculated for each country as described in Table 1. For illustrative purposes, the market indicators and other input factors were collected for 2003. To ensure reasonableness of their relationships with trade output, the six trade performance factors were collected for 2004 to create a 1-year lag. All data were matched by country. The correlation matrix is reported in Table 2 for trade, logistics infrastructure, national accounts and development data variables.

Ethical consideration

This article followed all ethical standards for a research without direct contact with human or animal subjects.

Results

The results are presented in three sections below. Firstly, the results from the DEA efficiency analysis are presented;

TABLE 2: Correlation matrix.

Regression variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Telemobl	1	-	-	-	-	-	-	-	-	-	-	-
2. Lnxdays	-0.649**	1	-	-	-	-	-	-	-	-	-	-
3. RailDens	0.435**	-0.280**	1	-	-	-	-	-	-	-	-	-
4. RoadDens	0.481**	-0.473**	0.118	1	-	-	-	-	-	-	-	-
5. RurlDens	-0.003	0.062	-0.138	0.077	1	-	-	-	-	-	-	-
6. Remit	-0.113	0.093	-0.159	-0.024	0.127	1	-	-	-	-	-	-
7. Airfrt	0.385**	-0.282**	-0.163	0.373**	0.196	-0.025	1	-	-	-	-	-
8. Trnsptsvc	0.084	0.081	-290**	0.086	-0.024	0.067	-0.006	1	-	-	-	-
9. Fuelratio	-0.116	0.079	-0.171	-0.112	-0.012	0.025	-0.032	-0.043	1	-	-	-
10. Servratio	0.268*	-0.291**	0.138	-0.012	-0.225*	-0.211*	-0.093	-0.082	-0.111	1	-	-
11. Foodratio	-0.179	0.051	-0.002	-0.242*	-0.115	-0.013	-0.147	-0.115	-0.145	0.062	1	-
12. Hitechexp	0.308**	-0.284**	-0.012	0.266*	-0.011	0.104	0.416**	-0.037	-0.131	-0.013	-0.08	1
13. Cduty	-0.310**	0.206	-0.250*	-0.166	0.024	0.331**	-0.139	-0.053	-0.048	-0.164	-0.028	0.158

$N = 89$.

Telemobl, number of main line and mobile phone subscribers per 1000 people; Lnxdays, natural log of the average time (days) to export a standard shipping container; RailDens, kilometers of usable rail per 1000 people; RoadDens, kilometers of roadways per 1000 square-kilometer; RurlDens, rural population per square-kilometer of arable land; Remit, workers' remittances as percentage of GDP; Airfrt, air freight shipments in million tons per kilometer; Trnsptsvc, ratio of export versus import related transportation as percentage of commercial services; Fuelratio, ratio of fuel exports to imports as percentage of merchandise exports; Servratio, ratio of exports versus imports in current (2004) U.S. dollars; Foodratio, ratio of food exports to imports as percentage of merchandise exports; Hitechexp, high-tech exports as a percentage of manufacturing exports; Cduty, customs and other import duties as percentage of total tax revenue.

*, Correlation is significant at the 0.05 level (2-tailed).

**, Correlation is significant at the 0.01 level (2-tailed).

these efficiency scores are necessary in the estimation of the regressions in Equation 2. Next are the results for two proposed models: H1 – Equation 1 is presented first, followed by H2 – Equation 2.

Results of the data envelopment analysis efficiency analysis

Table 3 reports the efficiency scores for the 89-country data set, with each country categorised as efficient if the score was equal to 1.0, or inefficient otherwise. It is noteworthy to observe that not every developed country was determined to be *efficient* (e.g. the United Kingdom with a score of 0.893), and that several small- and medium-sized countries were determined to be relatively efficient (e.g. Costa Rica with a score of 1.0). This should not be interpreted to mean that Costa Rica has a 'better' supply chain infrastructure than the United Kingdom in the sense that (for example) the roads or railroads are more numerous or in better condition (i.e. efficiency scores say nothing about the question of which country has good or bad infrastructure). Rather, a score of 1.0 for Costa Rica means that it is not possible to (1) increase outputs without increasing inputs or (2) decrease inputs without decreasing outputs. For the United Kingdom, on the other hand, it is possible to increase outputs without increasing inputs or to decrease inputs without decreasing outputs. The United Kingdom has excess capacity or infrastructure slack, whilst Costa Rica is operating at full infrastructure capacity.

To explore this further, Table 4 compares efficient versus inefficient countries (a dichotomous variable called Efficiency Category or EFFCAT) firstly on trade and infrastructure in Panel A, and then by MPIs in Panel B. The table lists the means and standard deviations for the two EFFCAT groups and reports in the last column whether they are significantly different from one another. The analysis of variance (ANOVA) results offer several insights. Firstly, by a factor of nearly 3, efficient countries tend to move much larger volumes of airfreight tonnage annually ($p < 0.05$). Secondly, food trade (ratio of food exports to imports) was higher for efficient

TABLE 3: Country efficiency scores.

Country	Efficiency	Rank
Algeria	1	1
Argentina	1	1
Australia	1	1
Bangladesh	1	1
Bolivia	1	1
Brazil	1	1
Canada	1	1
Chile	1	1
China	1	1
Costa Rica	1	1
Denmark	1	1
Dominican Rep	1	1
Egypt	1	1
Estonia	1	1
Finland	1	1
Germany	1	1
Ghana	1	1
Guatemala	1	1
Hong Kong	1	1
India	1	1
Indonesia	1	1
Ireland	1	1
Israel	1	1
Japan	1	1
Kenya	1	1
Malaysia	1	1
Morocco	1	1
Mozambique	1	1
Nepal	1	1
Netherlands	1	1
New Zealand	1	1
Nigeria	1	1
Norway	1	1
Pakistan	1	1
Panama	1	1
Peru	1	1
Russia	1	1
Saudi Arabia	1	1
Singapore	1	1
Slovak Republic	1	1
Syria	1	1

Table 3 continues on the next page →

TABLE 3 (Continues...): Country efficiency scores.

Country	Efficiency	Rank
Tunisia	1	1
Turkey	1	1
UAE	1	1
Ukraine	1	1
Uruguay	1	1
Venezuela	1	1
Vietnam	1	1
Senegal	0.999886	49
Switzerland	0.92434	50
South Africa	0.910188	51
Kuwait	0.90517	52
US	0.899378	53
Sweden	0.898795	54
United Kingdom	0.893167	55
Thailand	0.876983	56
Philippines	0.865562	57
Belarus	0.837229	58
Paraguay	0.820453	59
Ecuador	0.816596	60
Colombia	0.810524	61
Hungary	0.793819	62
Greece	0.743014	63
Romania	0.71669	64
Lithuania	0.712099	65
South Korea	0.708627	66
Spain	0.701337	67
Belgium	0.697959	68
Croatia	0.683716	69
Czech Republic	0.667562	70
Austria	0.659908	71
Honduras	0.600407	72
Mexico	0.583753	73
Latvia	0.575841	74
Poland	0.569178	75
Bulgaria	0.562447	76
Italy	0.5592	77
Mongolia	0.552097	78
Slovenia	0.545238	79
France	0.507428	80
El Salvador	0.492201	81
Portugal	0.469027	82
Azerbaijan	0.38853	83
Armenia	0.358425	84
Yemen	0.238992	85
Albania	0.157985	86
Moldova	0.140278	87
Sri Lanka	0.123473	88
Jordan	0.076100	89

Rep, Republic; UAE, United Arab Emirates; US, United States.

countries ($p < 0.05$). Thirdly, there was 50% more usable rail capacity per 1000 km^2 amongst the inefficient countries ($p < 0.01$). Note that we did not consider rates of utilisation, however. Finally, there were 40 % more phone and landline subscribers in the inefficient group. This difference was significant ($p < 0.10$).

Regression results for H1: Equation 1

Table 5 reports results for the OLS regressions for five of the seven dependent variables. Food ratio and fuel ratio are not shown because these regressions were non-significant ($p > 0.10$).

TABLE 4: Comparison of efficient versus inefficient markets.

Variable	Efficient countries (n = 47)	Inefficient countries (n = 42)	Results for the one-way ANOVA testing efficient vs. inefficient countries
Panel A: Infrastructure and trade			
Customs Duties	12.242 (25.31)	9.295 (16.06)	Cduty †EFFCAT F = 0.375, p = 0.542 n.s.
Air Freight	11.209 (20.05)	3.508 (8.95)	Airfrt †EFFCAT F = 4.561, p = 0. 036
Transport Services	0.976 (0.92)	0.998 (0.68)	Trsptsvc †EFFCAT F = 0.015, p = 0.904 n.s.
Services Ratio	0.977 (0.92)	0.998 (0.68)	Servratio †EFFCAT F = 0.011, p = 0.915 n.s.
Hitechexp Ratio	14.97 (16.15)	9.41 (7.49)	Hitech †EFFCAT F = 2.56, p = 0.113 n.s.
Food Ratio	2.031 (2.01)	1.138 (0.63)	Foodratio †EFFCAT F = 6.479, p = 013
Fuel Ratio	13.168 (53.4)	1.536 (4.12)	Fuelratio †EFFCAT F = 1.647, p = 0.203 n.s.
Worker Remittances	4.173 (6.65)	6.898 (17.06)	Remit †EFFCAT F = 1.120, p = 0.239 n.s.
Rural Density	1.710 (2.45)	2.214 (1.86)	RurlDens †EFFCAT F = 1.074, p = 0.303 n.s.
Road Density	6.046 (9.19)	8.989 (9.42)	RoadDens †EFFCAT F = 2.137, p = 0.147 n.s.
Rail Density	0.293 (0.24)	0.435 (0.26)	RailDens †EFFCAT F = 7.263, p = 0.008
Days to export (log)	2.77 (0.618)	2.841 (0.459)	lnxdys †EFFCAT F = 0.389, p = 0.534 n.s.
Land/Mobile phone	0.531 (0.49)	0.724 (0.50)	Telemobl †EFFCAT F = 3.156, p = 0.079
Panel B: Market potential indicators			
Country Risk	0.433 (0.295)	0.464 (0.317)	F = 0.216, p = 0.643 n.s.
Market Size	0.099 (0.179)	0.049 (0.062)	F = 2.661, p = 0.106 n.s.
Market Growth	0.411 (0.178)	0.390 (0.240)	F = 0.213, p = 0.646 n.s.
Market Receptivity	0.146 (0.178)	0.128 (0.084)	F = 0.305, p = 0.582 n.s.
Market Structure	0.575 (0.261)	0.651 (0.212)	F = 2.054, p = 0.155 n.s.
Market Intensity	0.500 (0.276)	0.524 (0.224)	F = 0.190, p = 0.664 n.s.

Note: Means and Std. Dev. in parentheses for the variable.

Numbers in second and third columns present the means and std. deviation (in parenthesis) of each variable, in the first column, for efficient and inefficient countries, respectively.

n.s., non-significant; Std. Dev., standard deviation; ANOVA, analysis of variance.

†, EFFCAT, efficiency category (a grouping variable for efficient vs. inefficient countries).

TABLE 5: Results for regressions for Equation 1*.

Independent variables (for variables above adj. R-squared)	Cduty	AirFrt	TrnspSvc Ratio	Serv Ratio	Hitech Ratio
Remit	0.299 (.004)	n.s.	n.s.	n.s.	n.s.
RurlDens	n.s.	n.s.	n.s.	−0.208 (.043)	n.s.
RoadDens	n.s.	0.304 (.007)	n.s.	n.s.	n.s.
RailDens	−0.203 (.047)	−0.258 (.012)	0.29 (.006)	n.s.	n.s.
Lnxdys	n.s.	−0.21 (.066)	n.s.	−0.278 (.007)	n.s.
Telemobl	n.s.	n.s.	n.s.	n.s.	0.264 (0.08)
Adj. R-squared	0.13	0.187	0.074	0.107	0.097
F-value	7.566	7.775	7.993	6.287	2.575
Significance	p = 0.001	p = 0.00	p = 0.006	p = 0.003	p = 0.025

Note: Foodratio and Fuelratio are not shown because these regressions were n.s.

Cduty, customs and other import duties as percentage of total tax revenue; Airfrt, air freight shipments in million tons per kilometer; Trnsptsvc, ratio of export versus import related transportation as percentage of commercial services; Serv Ratio, ratio of exports versus imports in current (2004) U.S. dollars; Hitech Ratio, high-tech exports as a percentage of manufacturing exports; Remit, workers' remittances as percentage of GDP; RurlDens, rural population per square-kilometer of arable land; RoadDens, kilometers of roadways per 1000 square-kilometer; RailDens, kilometers of usable rail per 1000 people; Lnxdays, natural log of the average time (days) to export a standard shipping container; Telemobl, number of main line and mobile phone subscribers per 1000 people; Adj., adjusted.

*, Betas, with p-values in parentheses; n.s. – non-significant ($p > 0.10$).

Overall, the regression R^2 results show that dimensions of infrastructure seem to be relevant in particular to predict customs duties (Cduty overall $R^2 = 0.130$; $p < 0.001$), airfreight movement (Airfrt overall $R^2 = 0.187$; $p < 0.001$) and commercial service exports (Servratio overall R^2 = 0.107; p = 0.003).

TABLE 6: Regression results for Equation 2*.

Regression statistics (For adj. R-squared and the statistics below)	Cduty	AirFrt	TrnspSvc ratio	Serv ratio	Hitech ratio	Food ratio	Fuel ratio
Macro Logistics System							
Remit (β_1)	+***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
RurlDens (β_2)	n.s.	n.s.	n.s.	-**	-*	n.s.	n.s.
RoadDens (β_3)	n.s.	n.s.	n.s.	-**	n.s.	n.s.	n.s.
RailDens (β_4)	n.s.	n.s.	+***	n.s.	n.s.	n.s.	n.s.
Lnxdys (β_5)	n.s.	+*	n.s.	-***	n.s.	n.s.	n.s.
Telemobl (β_6)	n.s.	n.s.	n.s.	+***	+*	n.s.	-**
Interaction Effects							
DEA*Remit (β_7)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
DEA*RurlDens (β_8)	n.s.	+*	n.s.	n.s.	+**	n.s.	n.s.
DEA*RoadDens (β_9)	n.s.	+**	n.s.	n.s.	n.s.	n.s.	n.s.
DEA*RailDens (β_{10})	n.s.	-***	n.s.	n.s.	n.s.	n.s.	n.s.
DEA*Lnxdays (β_{11})	+*	n.s.	n.s.	n.s.	n.s.	+**	n.s.
DEA*Telemobl (β12)	n.s.	+***	n.s.	n.s.	n.s.	-*	n.s.
Market Potential							
Crisk (β_{13})	n.s.	n.s.	-**	n.s.	n.s.	-**	+**
Mktsz (β_{14})	n.s.	+***	n.s.	-*	+*	n.s.	-*
MktGrth (β_{15})	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
MktRecpt (β_{16})	n.s.	+***	n.s.	n.s.	+***	n.s.	n.s.
MktInten (β_{17})	-*	n.s.	+**	n.s.	n.s.	n.s.	+*
MktStruc (β_{18})	n.s.	n.s.	n.s.	n.s.	n.s.	+***	-***
Adj. R-squared	0.207	0.647	0.243	0.24	0.272	0.219	0.128
F-value	4.820	15.640	3.023	2.741	6.470	3.739	1.998
Significance (p-value)	0.000	0.000	0.000	0.002	0.000	0.000	0.032

Note: Bold indicates statistically significant data.

Signs + or — indicate direction of the estimated relationships.

Cduty, customs and other import duties as percentage of total tax revenue; AirFrt, air freight shipments in million tons per kilometer; TrnspSvc, ratio of export versus import related transportation as percentage of commercial services; Servratio, ratio of exports versus imports in current (2004) U.S. dollars; Telemobl, number of main line and mobile phone subscribers per 1000 people; Lnxdys, natural log of the average time (days) to export a standard shipping container; RailDens, kilometers of usable rail per 1000 people; RoadDens, kilometers of roadways per 1000 square-kilometer; RurlDens, rural population per square-kilometer of arable land; Remit, workers' remittances as percentage of GDP; Hitech ratio, high-tech exports as a percentage of manufacturing exports; Fuelratio, ratio of fuel exports to imports as percentage of merchandise exports; Foodratio, ratio of food exports to imports as percentage of merchandise exports; Crisk, country risk; Mktsz, market size; MktGrth, market growth; MktRecpt, market receptivity; MktInten, market intensity; MktStruc, market structure; DEA, Data Envelopment Analysis Efficiency Score; Adj., Adjusted; n.s., non-significant.

*, Significance at 0.1 level; **, at the 0.05 level; ***, at the 0.01 level.

Customs duties were significantly and positively related to total workers' monetary remittances (Remit, $p = 0.004$), whilst railroad density was negatively related (RailDens, $p = 0.047$). A 10% increase in remittance flows from expatriates leads to a 3% increase in customs duties. Tonnage of airfreight moved was positively related to road density (RoadDens, $p = 0.007$), and negatively related to both railroad density (RailDens, $p = 0.012$) and customs clearance time (Lnxdys, $p = 0.066$). The value of transportation services (Trnspsvcratio, overall $R^2 = 0.074$) was significantly influenced by railroad density (RailDens, $p = 0.006$), but explanatory power was low. Trade in commercial services was negatively related to rural population density (RurlDens, $p = 0.043$) and shipping container customs clearance time (Lnxdys, $p = 0.007$). Finally, export or import ratios of high-technology manufactured products (Hitechratio overall $R^2 = 0.097$; $p = 0.025$) was positively related to subscriber density only (Telemobl, $p = 0.080$).

Regression results for H2: Equation 2

The results of Equation 2 are presented in Table 6. The seven independent variables are listed column-wise. The three sets of dependent variables are listed in rows: firstly, Equation 1's six logistics infrastructure and development dimensions ($\beta_1 - \beta_6$); next, the six corresponding efficiency interaction effects ($\beta_7 - \beta_{12}$), each indicated by DEA*{____}; and, finally, the six MPIs ($\beta_{13} - \beta_{18}$). All statistically significant cells in the table are shaded ($p < 0.01$, 0.05 or 0.10) and a '+' or '−' sign indicates the direction of the relationship. At the bottom of the table, the overall model statistics are shown; every model is significant at $p < 0.05$. By far the best adjusted R-squared is for airfreight (overall $R^2 = 0.647$), and the worst is for fuel ratio (overall $R^2 = 0.128$).

Customs duties (Cduty overall $R^2 = 0.207$; $p < 0.01$) are significant and positively related to workers' remittances received (Remit, $p < 0.01$). The efficiency interaction for container export is also marginally significant and positive (DEA*Lnxdys, $p < 0.10$). One MPI was significantly related: market intensity's beta was negative (MktInten, $p < 0.005$). Tonnage airfreight movements (Airfrt overall $R^2 = 0.647$; $p < 0.01$) was significant and positively related to market size (Mktsz, $p < 0.01$) and market receptivity (MktRecpt, $p < 0.01$), as well as container export time (Lnxdys, $p < 0.10$). There were also significant and positive relationships regarding structural differences (efficiency interactions) with rural population density (DEA*RurlDens, $p < 0.05$), road densityx (DEA*RoadDens, $p < 0.05$) and number of phone subscribers (DEA*Telemobl, $p < 0.01$), whilst the DEA*RailDens interaction relationship was significant and negative ($p < 0.01$).

Transportation services export or import ratio (Trnspsvcratio overall $R^2 = 0.243$; $p < 0.01$) was significant and positively related to market intensity (MktInten, $p < 0.05$) and railroad density (RailDens, $p < 0.01$). Country risk (Crisk, $p < 0.05$) was negative. None of the interaction effects (representing structural differences) was significant in this model. Commercial services export or import ratio (Servratio overall $R^2 = 0.240$; $p < 0.01$) was significant and positively related to phone subscriber density (Telemobl, $p < 0.01$). There were also significant yet negative relationships to rural density (RurlDens, $p < 0.05$), road density (RoadDens, $p < 0.05$), container export time (Lnxdys, $p < 0.01$) and market size (Mktsz, $p < 0.10$). No interaction effect was significant.

The ratio of high-technology exports as a per cent of total manufactured goods (Hitechratio overall $R^2 = 0.272$; $p < 0.01$) was significant and positively related to phone subscribers (Telemobl, $p < 0.10$), market size (Mktsz, $p < 0.10$) and market receptivity (MktRecpt, $p < 0.01$), whilst it was negatively related to rural population density (RurlDens, $p < 0.10$). For the efficiency interaction terms, positive relationships were observed for rural population density only (DEA*RurlDens, significant at $p < 0.05$). For the ratio of food product exports to imports (Foodratio overall $R^2 = 0.219$; $p < 0.01$), no significant main effects were observed for any of the six core variables. For the efficiency interaction terms, there was a significant positive relationship for container export time (DEA*Lnxdys, $p < 0.05$) and a negative relationship for phone subscribers (DEA*Telemobl, $p < 0.10$). For MPIs, country risk (Crisk, $p < 0.05$) was negatively related and market structure was positively related to the food ratio (MktStruc, $p < 0.01$). The ratio of fuel and energy exports to imports (Fuelratio overall $R^2 = 0.128$; $p = 0.032$) was negatively related to phone subscribers (Telemobl, $p < 0.05$). None of the interaction effects (representing structural differences) was significant in this model. In terms of MPIs, both country risk (Crisk, $p < 0.05$) and market intensity (MktInten, $p < 0.10$) were positive and significant, whilst market size (Mktsz, $p < 0.10$) and market structure (MktStruc, $p < 0.01$) were negative and significant.

Discussion

This study proposed relationships between trade performance and logistics infrastructure, structural efficiencies and market potential; it explored these relationships using secondary data from 89 economies. Data envelopment analysis (for efficiency scores) and OLS regression were used to demonstrate the importance of both logistics infrastructure and market potential in determining trade performance. We have offered insights into the connection between macro logistics capability, efficiency and the performance of national environments or countries.

Equation 1 had six macro-logistics variables serving as the independent variables in six regressions. Overall, the results of Equation 1 (H1) show that (1) five of the seven independent variables studied were significantly predicted by at least one of the six independent variables; (2) of the five significant models, two were predicted by exactly one independent variable; and (3) in several instances, negative relationships were unexpectedly found. These mixed results were perhaps partly because of country-level differences in MPIs or because of differences in structural efficiencies, none of which were included in Equation 1. Thus, our motivation for examining Equation 2 (H2) seems validated.

Equation 2 had six macro-logistics variables, six corresponding efficiency interaction effects and six MPIs, for a total of 18 independent variables in each of the seven regressions. Overall, *inclusion of efficiency considerations and market potential improved these models over the baselines* estimated in Equation 1. The results of Equation 2 show that all seven regression models were significant overall (in terms of model *p*-values). In addition, each of the seven dependent variables was predicted by at least three of the independent variables. Overall, our proposed dependent and independent variables as modelled in the hypothesised Equation 2 seem to account for a substantial proportion of the variance in the data.

In four of seven significant models, at least one of the efficiency interaction components was significant, supporting the idea that structural efficiency is important. In particular, there are significant country-level differences in the ability to move air freight efficiently, and these seem to be partly because of structural differences, as calculated using DEA-derived efficiency scores and modelled as moderation effects. In all seven significant models, at least one of the MPIs was significant, supporting the notion that country differences in market potential make a difference. In particular, amongst MPI variables, the assembly or production of high-technology products for export, as well as airfreight, seems highly dependent on market size and receptivity. Assuming these specific types of high-tech products are frequently moved via airfreight, it is interesting to observe the consistency in direction and significance of these two MPIs.

Conclusion

We presented a discussion of logistics and supply chain infrastructure indicators, market potential and trade performance in the context of efficiency estimations. It is important to observe that our analysis shows there are several resource-capacitated countries that were determined to be DEA efficient in our modelling. Thus, the designation as a 'good performing' country is not (and should not be) reserved for large-sized countries or markets with high levels of macro-logistics capability as reported in our data set. Improving macro-logistics capability has become an important development policy objective for many governments and industry-based organisations because supply chain infrastructure is considered critical in attracting and sustaining business activity in developed and developing economies alike. Decision-makers must also understand and monitor the country-specific and regional environment context as they design supply chain strategies and execute market selection or entry plans; overall market potential is important. This study offers insights and motivates the need for more academic research on other perspectives related to measuring and comparing macro-logistics infrastructure, market potential, efficiency and trade performance. This might set the stage for bringing together policymakers and leaders in the private sector for collaborative investments aimed at further facilitating trade and improving the scope and efficiency of logistics and supply chains.

This stream of work could be extended by examining (1) other dimensions related to infrastructure or trade (i.e. other variables within the categories established in this research) or (2) relevant categories other than those considered here, e.g., this research focused on country as the unit of analysis, but these countries could be divided into regions or clusters; or they could be classified into those that are landlocked, that are island nations (e.g. Indonesia, New Zealand and others) or that have large coastal regions. As another example, consider such variables as terrain size, the location of shipping ports and the access to population centres via air or land transport. Improving roadway and railway network densities can influence the distribution of imports to local consumers as well as producers' abilities to export their goods. Density is not the same as efficiency (we considered only efficiency); for some countries, density per square mile or per population may be an informative metric. Finally, our findings are not restricted to a given industry. Some industries may have specific logistics requirements that are not modelled in this research. Future studies should include an investigation that segments the countries into groups (e.g. geographic regions or World Bank income classifications, or World Trade Organization (WTO) developed vs. EMs). Together, these limitations represent future research opportunities.

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The authors have declared that no competing interests exist.

Authors' contributions

All authors contributed equally to this work.

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