The impact of logistics performance on the achievement of the UN Sustainable Development Goal 2: Zero hunger

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Abstract

This study focuses on the role that international logistics performance may play in achieving Sustainable Development Goal 2 (Zero Hunger). We conducted a confirmatory piece of research to determine the potential importance of regional logistics coordination. Secondary data concerning the Logistics Performance Index (LPI) by the World Bank and the SDG2 scores by the UN database were examined at the level of countries and regions. The analysis considers an unconditional growth model with time as the only fixed effect and random effects of time within regions and countries. The findings show that LPI is a good predictor for SDG2 level of achievement; however, there are other sources for important variation between and within regions. Therefore, when developing and implementing strategies for the improvement of international logistics performance specific regional needs should be considered. Anyway, there is a global consensus among logistics professionals that the most impactful LPI component is 'Customs', which needs improvement across all the regions of the world. Other priorities vary depending on the region under study. For instance, developed countries are particularly sensitive to shipment costs, whilst less developed countries' concerns focus on improving their infrastructure.

Keywords Food security; Logistics Performance Index (LPI); Supply Chain Management; Sustainable Development Goals; Sustainability; Zero Hunger.

Paper type Research paper

1. Introduction

This paper investigates the relevance of international logistics performance towards the achievement of the United Nations (UN) Sustainable Development Goal 2 (SDG2), Zero Hunger. The rationale behind investigating international logistics performance as a driver to achieve Zero Hunger is the assumption that trade logistics facilitate trade (Korinek and Sourdin, 2011), hence, it seems reasonable to expect that an increase in the effectiveness of international logistics activities should result in a positive impact on export trade (Yugang and Renhong, 2021), an effect that should cascade on efforts to achieve zero hunger. Links between agriculture, international trade, and food security have been drawn in the past. For instance, FAO (2015) presented contrasting narratives, some considering food international trade an opportunity for food security, whilst others arguing that it is a threat. For instance, De Schutter (2011) proposed to limit excessive reliance on international trade when pursuing national food security. He pointed out that most of the agricultural international trade concerns processed food (above 80%), meanwhile grains and commodities are the big losers. This explains why developing countries focused on monoculture (e.g., cocoa, coffee, tea) have increased their food dependency, due to the reduction of agricultural spaces allocated to food production. In the same vein, previous work from Mary (2019) suggests that countries should probably reduce their food trade openness as a temporary strategy to achieve food self-sufficiency. Mary's findings indicate that (a) increasing food trade openness by 10% would result in an increase of undernourishment prevalence by around 6%, and (b) a 1% percentage point increase in undernourishment prevalence results in a 0.9% decrease in food trade openness. Conversely, other studies argue there are benefits to trade openness. For instance, Levine and Rothman (2005) found positive links between trade and lower infant and child mortality and lower stunting (height for age); they also found positive impact on trade and higher life expectancy. Furthermore, Dithmer and Abdulai (2017) claimed that trade openness impacts food security in a positive and highly statistical way.

Higher levels of global food security concern the physical movement of goods, trade across borders, and commerce within borders, and include diverse logistics activities, such as brokerage, express delivery, infrastructure services, and warehousing (World Bank, 2018). However, to succeed in increasing global food security a series of issues must be addressed. These can be categorized into five dimensions (Caspi *et al.*, 2012; Turner *et al.* 2021): (1) *accessibility* in terms of location of food sources; (2) *affordability*, related to food price and consumer perception; (3) *availability*, as the adequacy of food supply; (4) *acceptability*, to consider consumer's attitudes to products, and (5) *accommodation*, how interactions between sources and customers are regulated. Two of these dimensions (*accessibility* and *availability*) require an efficient and well-operating food logistics system, particularly in terms of adequate infrastructure and performance (Abbade, 2020). This is a big challenge as significant

infrastructure upgrades in the next few decades are required to meet the increased demand for food (Keating, 2013). *Affordability* has also been linked to effective logistics, and how food supply chains should be built and managed. For instance, current food supply structures reward the use of long food supply chains, which tend to reduce inefficiencies in normal times, but have no margin to operate in moments of crisis (Keating, 2013) making food prices rise. This indicates that shortening food supply chains could be part of the solution to increase affordability and food security (United Nations, 2022).

Considering that logistics is a vital element of the food supply chain, in terms of delivering the right product and quantity at low cost and on time with minimum or no food waste (Jagtap *et al.*, 2021), it is surprising to find so scarce academic literature that investigates the relationship between logistics performance and Zero Hunger (SDG2). Initial explorations using LPI scores suggested a potential impact of logistics performance on the achievement of SDGs (Vilalta-Perdomo *et al.*, 2019; Vilalta-Perdomo and Michel-Villarreal, 2020). More specifically, Abbade (2020) found that there is a negative and significant correlation between logistics performance and the prevalence of undernourishment, suggesting that countries with better logistic performance tend to have a lower prevalence of population undernourishment (SDG2 indicator 2.1.2). However, Allee *et al.* (2021) found mixed results when looking at the predictive power of logistics performance for calculating national food security. Furthermore, Zawawi *et al.* (2018) did not recognize links between logistics operations and SDG2. Therefore, this paper aims to confirm or reject a potential correlation between countries' international logistics performances and their level of achievement concerning SDG2, Zero Hunger.

The paper is structured as follows: First, a literature review that revisits different sources about the Sustainable Development Goals (SDGs) and the Logistics Performance Index (LPI); second, a section concerning secondary data and methods; third, a description of the empirical strategy; fourth, a presentation of results; fifth, a discussion on the findings, and finally, conclusions and future research.

2. Literature review

2.1 Sustainable Development Goal 2, SDG2

It was Malthus (1798) who published a critique on the accelerated velocity towards illimitable, and hitherto unconceived improvement, as this approach would trap us in a perpetual oscillation between happiness and misery. This seems to be contradicted by scientific achievements that have allowed incredible productivity gains, through selective breeding and protection of crops, which led to massive increases in crop yield, and better storage and transportation of food. However, closer to our times, other voices have continued raising concerns; for instance, *Road to Survival* (Vogt, 1948) and *Limits to Growth* (Meadows *et al.*, 1972). Nevertheless, it was not until the Brundtland Report (1987) that international concerted actions to achieve sustainable development were asked: "to propose long-term

environmental strategies for achieving sustainable development by the year 2000 and beyond" (United Nations, 1987). For this purpose, in 2015, a set of Sustainable Development Goals (SDGs) became part of the UN Agenda 2030. SDGs call for collective action by all countries who signed the agenda.

To assess the SDGs' progress, a 2018 Global SDG Index and a set of Dashboards were developed to provide a comprehensive assessment of distance to targets. Data covering all 193 UN member States include a mix of official and non-official data sources, such as international organizations (e.g., World Bank, OECD, WHO, FAO, ILO, UNICEF), household surveys (e.g., Gallup World Poll), civil society organizations and networks (e.g., Oxfam, and Tax Justice Network) and peer-reviewed journals (e.g., Journal of Industrial Ecology, Journal of Economic Structures, Nature, and Nature Climate Change).

Concerning possible links between SDGs and supply chains, recently there have been some studies focused on answering questions, such as: how companies enact traceability in their global supply chains to achieve sustainability goals (García-Torres *et al.*, 2019); how the textile and apparel (TA) supply chains can comply with the SDGs (Cai and Choi, 2020); which is the influence of enabling technologies and green practices in freight transport and logistics service industry (Centobelli *et al.*, 2020); which is the influence of the top management support on SDGs in SMEs (Ilias *et al.*, 2020), and how to develop a supply chain management sustainability index (Said *et al.*, 2020). However, as indicated above, the relationship between SDG2 and international logistics performance has received little attention.

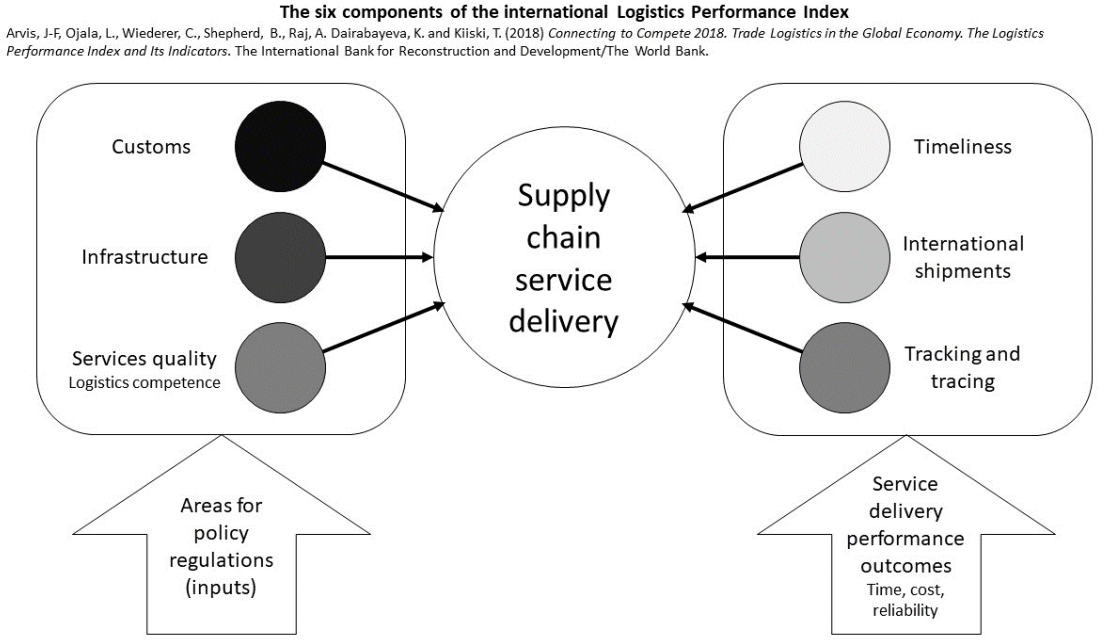
2.2. Logistics Performance Index (LPI)

The Logistics Performance Index (LPI) is an interactive tool created for benchmarking logistics practices between most countries in the world (Batista, 2012). The main aim is to help countries to identify challenges and opportunities concerning their performance in trade logistics. The LPI is a biennial exercise that allows for comparisons across 160 countries (World Bank, 2018).

The LPI international dimension is a summary indicator of logistics professionals' experiences when operating in foreign countries. The questionnaire is built around six core performance components. The questions collect the different experiences that logisticians have had in eight randomly selected countries between the most important export and import markets. These six core performance components are rated through a Likert scale, from "very low" (1) to "very high" (5), and consider: the efficiency of customs and border clearance; the quality of trade and transport infrastructure; the ease of arranging competitively priced shipments; the competence and quality of logistics services; the ability to track and trace consignments, and the frequency with which shipments reach consignees within scheduled or expected delivery times (see Figure 1). The answers are used to build a single aggregate measure of international LPI, using a principal component analysis (PCA) to

reduce the dimensionality of the dataset (Jaramillo *et al.*, 2018). The main benefit of using PCA is that it increases interpretability, whilst minimizing information loss (Jolliffe and Cadima, 2016).

Figure 1. The six components of the international Logistics Performance Index



Source: Adapted from Jaramillo *et al.* (2018)

International LPI provides the score profile of 160 countries, that have participated almost since the first edition in 2007. A convergence of scores from 2007 to 2014 was observed, mainly due to an improvement in the low- and middle-income countries' infrastructure. In 2018, the gap continued closing between top and bottom performers; however, high-income countries remain occupying the top 10 rankings – eight in Europe plus Japan and Singapore. Germany is at the top, followed by Sweden and Belgium. In the bottom of the ranking, 8 are in Africa, 1 in the Caribbean, and 1 in Central Asia.

Recently, the LPI concept and its associated dataset have been used to analyze different aspects within and beyond SDGs, such as a green logistics performance index (Hung Lau, 2011; Kim and Min, 2011); the association between the levels of food utilization (FU), food availability, economic access (EA) and physical access (PA) to food in developing countries (Abbade, 2017); the influence of corruption and gender inequality on logistics performance (Larson, 2019); maritime clusters in terms of attractiveness (Lagoudis *et al.*, 2019); LPI correlation with logistics commitments in exports and

imports (incoterms) (Stojanović and Ivetić, 2020), and the relationship between environmental factors, risk perception and decision-making in risk management (Sreedevi *et al.*, 2021).

However, there have been warnings concerning the validity of LPI. Some recommendations for its improvement have been proposed (Beysenbaev and Dus, 2020). Moreover, the World Bank (2018) has identified five issues that deserve attention when using LPI to assess a country's logistics performance. First, LPI is built through the responses to a survey, where logistics professionals express their personal views on how easy or difficult it is to undertake logistics in international operations. Second, the use of the overall LPI score is a more informative indicator than the LPI rank, as the differences in the LPI score between countries are not the same in different quintiles of the ranking. Third, LPI reflects better general merchandise rather than specialized (e.g., dangerous and food pharmaceutical products). Fourth, answers collected in poor, developing, and developed countries might not be easy to compare, as they come from actors that often have different expectations in terms of service level criteria for time or cost. Finally, in the specific case of landlocked countries and small island states, the LPI might not reflect the will to improve their trade facilitation reform efforts, because their success is fully intertwined with their neighbors' trade practices. To mitigate these limitations two main strategies have been implemented. First, questions 10–15 of the LPI survey are built to gather raw data for the international LPI, by asking opinions concerning eight overseas markets in terms of six core components of international logistics performance (i.e., customs, infrastructure, service quality/logistics competence, international shipments, tracing and tracking, and timeliness). The eight countries are randomly chosen from the most important export and import markets for each respondent's country. In the case of landlocked countries other considerations have also been taken, such as selecting neighboring countries that act as land bridges to other international markets. Second, The LPI was constructed from these six indicators through a principal component analysis (PCA); therefore, before conducting PCA, the six scores were normalized by subtracting the sample mean and dividing it by the standard deviation, and the weighted average of such normalized scores became the LPI score. A more detailed description of how the LPI score is built can be found in Appendix 5 "LPI methodology" of the report "Connecting to Compete 2018. Trade logistics in the global economy" (World Bank, 2018).

Early evidence suggests that improving international logistics performance would result in progress towards the achievement of SDG2 (Abbade, 2020; Vilalta-Perdomo and Michel-Villarreal, 2020), but a link between LPI and SDG2 remains unexplored. It has also been suggested that significant changes in the logistics infrastructure and performance are required if our food system is to meet the increased demand for food in the next few decades and deliver food security (Keating, 2013). To make global flows grow more effectively and efficiently, public sector interventions must be considered. These can

take the form of regulations; investments in infrastructure; control and monitoring systems, especially of international goods, and the quality of public-private collaboration. Therefore, this paper focuses on better understanding the potential impact of countries' international logistics performance on their SDG2 achievement. It also investigates the changes that are needed to improve logistics performance in different regions of the world.

3. Data and methods

Zero hunger is currently measured by a set of UN goals and indicators; even though, surprisingly, none of them is directly related to international logistics performance. As indicated above, these indicators are the prevalence of undernourishment, the prevalence of stunting, the prevalence of wasting, the prevalence of obesity, human trophic level, cereal yield, and sustainable nitrogen management (Sachs *et al.*, 2020). Similarly, the World Bank (2018) has suggested a strong correlation between logistics performance and the quality of service, as can be observed when comparing the LPI components score by LPI quintile, but nothing seems to be linked to any of the SDGs. This barren knowledge area is what triggered us to undertake this research, to better inform the potential benefits that may derive from regional strategies that might improve international logistics performance, in the context of SDG2, Zero Hunger.

3.1 Units of analysis

The units of analysis consider countries nested in regions and years, with data concerning: (a) the level of achievement in the Sustainable Development Goal 2 (SDG2), and (b) the Logistics Performance Index (LPI) (see list of excluded countries due to lack of data availability in the appendix). Part of the rationale behind analyzing countries nested in regions is that recent figures related to food hunger show enduring and troubling regional inequalities. For instance, about one in five people (21 percent of the population) was facing hunger in Africa in 2020 – more than double the proportion of any other region (FAO, IFAD, UNICEF, WFP, and WHO, 2021). The benefits of conducting an analysis focused on countries nested in regions are, at least, twofold. First, it may provide further evidence of the benefits of designing more comprehensive regional policies to target inequalities and improve SDG2 achievements, by strengthening the international logistics performances of countries within each region. Second, it follows the recommendation to adopt a Systems Thinking approach (Parsons *et al.*, 2019), to succeed in achieving Zero Hunger by 2030. This implies taking regional food supply chains as the "system-in-focus", rather than continuing to develop a myriad of disconnected national programs, which sometimes translate into limited benefits.

3.2 Dependent variable

SDG2 level of achievement data used in this study is provided by SDG-Tracker.org. This indicator concerns "Goal 2 – end hunger, achieve food security and improved nutrition and promote sustainable agriculture", and is built using five targets that shall be achieved by 2030 and another three targets that have no target year (see Table 1). Thirteen indicators are used to measure the progress of these targets (see Table 1). Data is provided at the country level, but it is classified by regions according to the UN regional classification (i.e., Australia and New Zealand, Central and Southern Asia, Eastern and Southern-Eastern Asia, Europe and Northern America, Latin America and the Caribbean, Northern Africa and Eastern Asia, and Sub-Saharan Africa). The expectation is that improvements in a country's LPI score result in improvements in its SDG2 score, but the level of such improvements may differ between regions.

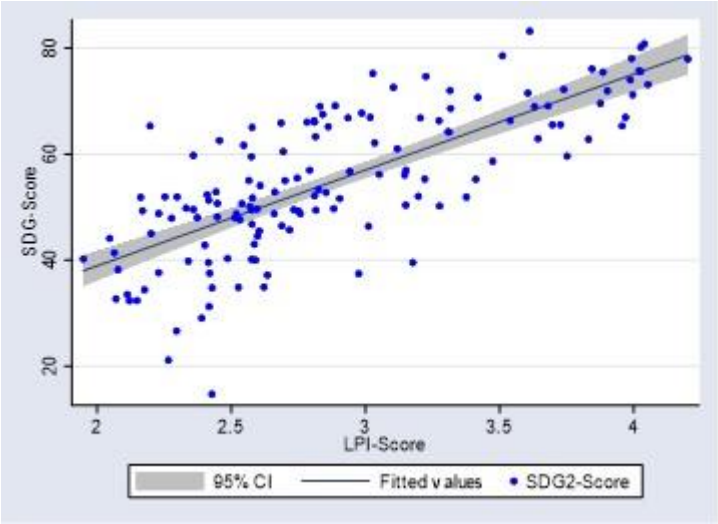
Table 1. SDG2 targets and indicators

Targets	Indicators
2.1. Universal access to safe and nutritious food.	2.1.1 Prevalence of undernourishment. 2.1.2 Prevalence of food insecurity.
2.2. End of all forms of malnutrition.	2.2.1 Prevalence of childhood stunting. 2.2.2 Prevalence of childhood malnutrition (wasting or overweight).
2.3. Double the productivity and incomes of small-scale food producers.	2.3.1 Production per labor unit. 2.3.2 Income of small-scale food producers.
2.4. Sustainable food production systems and resilient agricultural practices.	2.4.1 Sustainable food production.
2.5. Maintain the genetic diversity in food production.	2.5.1 Genetic resources in conservation facilities. 2.5.2 Local breeds at risk of extinction.
2.A. Invest in rural infrastructure, agricultural research, technology, and gene banks.	2.A.1 Agriculture orientation index. 2.A.2 Official flows to agriculture.
2.B. Prevent agricultural trade restrictions, market distortions, and export subsidies.	2.B.1 Agricultural export subsidies.
2.C. Ensure stable food commodity markets and timely access to information.	2.C.1 Food price anomalies.

3.3 Independent variable

Previous work suggests that LPI might be a good predictor for assessing SDG2 (Vilalta-Perdomo and Michel-Villarreal, 2020). A scatter diagram for LPI vs SDG2 shows the potential relationship between both variables – Spearman's rho correlation coefficient for 2016 LPI and SDG2 data is 0.702, and for 2018 data is 0.730 (see Figure 2). However, the scatter diagram does not provide further information concerning the potential impact of countries' international logistics performance depending on their regional location. This requires further statistical analysis.

Figure 2. Scatter diagram LPI Score vs SDG2 Score for 143 countries



Source: Own preparation

3.4 Statistical analysis

This paper aims to explore the relevance of improving logistics performance to contribute to the achievement of SDG2. Our main hypothesis is that this requires regional coordinated efforts between nations. We assume that SDG2 outcomes can be predicted through the LPI score, but significant differences are expected within and between regions. This suggests the need to build specific regionally coordinated initiatives and partnerships when developing national programs to achieve Zero Hunger. In this context, there is a need to recognize if a country's international logistics performance is affected by its regional location. To discover if this is the case, we first test for differences in medians in SDG2 levels across the 7 regions; if this is the case, then we would test the regional difference hypothesis based on a mixed-effects modeling approach.

4. Empirical strategy

Our data are longitudinal and geographically nested as we have repeated measures of SDG2 and LPI at the regional and country levels over time (2016 and 2018). Our data set has three levels: Level 1 represents the longitudinal measures of SDG2 and LPI, Level 2 represents the units of analysis, namely countries nested in regions, and Level 3 represents the clusters of units, the regions themselves. For these reasons, we employed a mixed-effects regression to estimate fixed effects with random effects at the region level of aggregation over time.

We first specify an unconditional growth model with time as the only fixed effect and random effects of time within regions and countries. This specification measures how much within-country

variability in SDG2 distribution is associated with change over time and how much variability is there across countries and regions (as random intercepts and slopes) over time. The unconditional growth model formulation is the following (Roback & Legler, 2021):

Level 1 (timepoint within countries): $Y_{ijk} = \alpha_{ij} + \beta_{ij} time_{ijk} + \epsilon_{ijk}$

Level 2 (countries within regions): $\alpha_{ij} = \alpha_i + u_{ij}$ and $b_{ij} = b_i + v_{ij}$

Level 3 (regions): $\alpha_i = \alpha_0 + \tilde{u}_i$ and $b_i = \beta_0 + \tilde{v}_i$

Or as a composite specification:

$$Y_{ijk} = [\alpha_0 + \beta_0 time_{ijk}] + [\tilde{u}_i + v_{ij} + \epsilon_{ijk} + (\tilde{v}_i + v_{ij}) time_{ijk}]$$

where $\epsilon_{ijk} \sim N(0, \sigma^2)$

In this formulation, at Level 1 the time trajectory for country j from region i is assumed linear, with intercept $alpha_{ij}$ (i.e., SGD2 on Time = 0) and slope $beta_{ij}$ (i.e., the growth rate between Time=0 and Time=1). The error term e_{ijk} measures the difference between the growth trajectory of country j from region i and its observed values. At l 2, $alpha_i$ signifies the actual mean intercept, and $beta_i$ signifies the actual mean slope for all countries from region i, as u_{ij} and v_{ij} capture the deviation between countries j's actual growth trajectory and the mean intercept and slope for region i. Lastly, at Level 3, $alpha_0$ is the actual mean intercept and $beta_0$ is the actual mean growth rate over the entire sample of countries, while tilde u_i and tilde v_i measure the difference between the region i's overall growth and the mean intercept and slope (Roback & Legler, 2021). The second specification is the conditional growth model in which the LPI variable is included in the equation as a fixed effect in Level 1 while measuring the same variance components as in the previous specification.

The dependent variable and independent variables were transformed to log10 scale. Log transformations help reduce error skewness and heteroscedasticity, while Z-scores help reduce multicollinearity in our moderation tests, eliminate the effect of different measurement units, and ensure comparability between regression coefficients. The method of restricted maximum likelihood (REML) was used to estimate model parameters, as it separates the data used for estimating fixed effects from random effects and is better able to provide unbiased estimates of variance components (Roback & Legler, 2021).

The software utilized were R (v. 3.3.1) and RStudio (v. 1.2.1335) in conjunction with the Linear and Nonlinear Mixed Effects Model (NLME) package (v. 3.1.148). Results with alpha less than 0.05 were considered statistically significant.

5. Results

Table 2 below shows the descriptive statistics of SDG2 and the LPI scores per year of measurement. We see noticeable differences in the mean levels as well as in the variances across countries in regions. For SDG2, it is observed that the mean value for Region 7 (Sub-Saharan Africa) is markedly lower as compared to the other regions. The same can be observed for the LPI score.

Table 2. SDG2 and LPI yearly means per region

		SDG2		LPI	
		2016	2018	2016	2018
Central & Southern Asia	1	52.996	62.552	2.487	2.543
Europe & North America	2	73.361	75.916	3.416	3.383
Latin America & Caribbean	3	58.454	66.257	2.664	2.664
Northern Africa & Western Asia	4	58.893	63.625	2.880	2.779
Australia and New Zealand	5	74.282	75.375	2.885	2.945
Eastern and Southern-Eastern Asia	6	59.194	67.536	3.121	3.133
Sub-Saharan Africa	7	42.516	52.854	2.467	2.484
	General	58.320	64.902	2.871	2.862

The results of the Shapiro-Wilks tests in Table 3 below also indicate that variables are not normally distributed either. Because of that, we apply Kruskal-Wallis tests of differences in the medians to test whether SDG2 and LPI score levels are similar across regions. In this case, we can also confirm that levels of both variables significantly vary across regions.

Table 3. Tests of normality and differences across regions

	SDG2		LPI	
	2016	2018	2016	2018
Shapiro-Wilks W statistic	0.975***	0.977***	0.956***	0.932***
Kruskal-Wallis Chi2 statistic	106.4***	112.2***	56.9***	62.3***

* p<0.1 ** p<0.05 *** p<0.01

Table 4 shows the results of our mixed effects regression models. Estimates of the random effects in the Unconditional growth model 1 show evidence of variability in the intercepts and slopes across countries and regions over time. The standard deviation of random slopes represents the standard deviation in rates of change in SDG2 levels in countries and regions. This is evidence that the effect of the passing of time between 2016 and 2018 on SGD2 was not homogeneous across countries and

regions. This also means that the fixed effect of time as an "average" effect, although statistically significant, does not fully capture the variation of SDG2 levels across units of analysis over time. Thus, although SDG2 levels increased by 0.052% on average between 2016 and 2018, random effects add to our understanding of the effect by showing evidence that SDG2 levels neither increased nor decreased for all countries nor by the same amount. In addition, the random effects residuals indicate significant variation in within-countries deviations to the observed SDG2 average after accounting for time.

Table 4. Linear mixed regression results (DV: SDG2 log10)

	Model 1 Unconditional model	Model 2 Conditional growth model
Fixed Effects:		
Time	0.051*** (0.012)	0.051*** (0.012)
LPI Score (log10)		0.173*** (0.034)
Intercept	1.764*** (0.031)	1.685*** (0.032)
Random Effects:		
Region:		
SD Intercepts	0.081	0.073
SD Time slopes	0.029	0.030
Correlation	-0.966	-0.968
Country:		
SD Intercepts	0.063	0.057
SD Time slopes	0.027	0.026
Correlation	-0.948	-0.929
SD Residuals	0.013	0.012
N (Regions)	7	7
N (Countries)	156	150
N (Time)	2	2
Obs.	306	286
AIC	-1,149.6	-1,086.2
BIC	-1,116.1	-1,049.7

* p<0.1 ** p<0.05 *** p<0.01

Note: Since they are logarithms in both cases, the coefficients of the fixed effects in the table are interpreted as elasticities or percentage changes.

As with Model 1, estimates of the random effects in Model 2 show evidence of variability in the intercepts and slopes across countries and regions over time. However, random effects decreased in their variation after introducing the LPI variable as a fixed effect predictor into the equation. Random effects residuals vary after accounting for time, suggesting that controlling for LPI levels, the correlation of time with SDG2 continued to vary across countries. In other words, the statistical association between the passing of time and SDG2 was not homogeneous across countries even after controlling for LPI levels.

6. Discussion

What do the results mean for policymaking and for supporting the efforts towards achieving Zero Hunger worldwide? Several insights emerge from the previous analysis of the data available. First, we have shown that the use of LPI scores provides a predictive capability for SDG2 achievements. Second, there is a worldwide convergency in the improvement of SDG2 through time; models 1 and 2 show a global improvement of 5% (see Table 4, time coefficient = 0.051) every two years; however, as less developed countries have smaller intercepts, there is a need to build an accelerated route to close such gaps. Third, concerning the gaps between regions and countries, model 2 shows that global strategies focused on improving sustainable logistics practices should not be neglected, as these can accelerate such convergence. Model 2 shows that a global increase in the LPI score of 1% would result in an improvement of SDG2 by 0.17% (see Table 4, LPI Score (log10) = 0.173); in other words, the impact of worldwide implemented logistics strategies that supports global trade more than triple improvements due to the pass of time. Fourth, it is not clear where to implement such a strategy as six different criteria constitute the LPI score: customs, infrastructure, international shipments, service quality/logistics competence, timeliness, and tracing and tracking; this requires further investigation. Finally, the fragility of global trade makes this difficult to achieve; for instance, see the effects of man-made disasters, such as the Russian invasion of Ukraine (Geijer, 2022; Topping, 2022; Wilks, 2022).

Concerning the predictive capability of LPI scores for identifying future SDG2 progress, this can be suggested by the high level of correlation shown. As indicated above, Spearman's rho correlation coefficient for 2016 LPI and SDG2 data is 0.702 and for 2018 data is 0.730 (see Figure 2). However, it is important to notice the differences shown between regions, and inside these, among countries. To check the differences, please refer to Table 5. As expected, the SDG scores from the less developed countries are smaller than those from the more developed. This indicates that global sustainable logistics strategies to increase SDG2 outcomes must pay special attention to less developed countries to close the current gap.

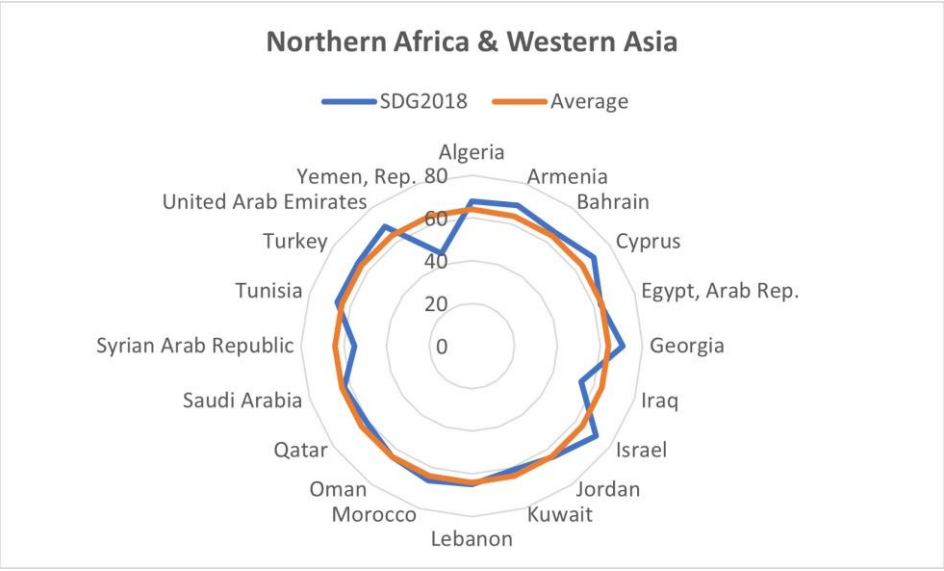
Table 5. SDG scores per region. Lower, average, and higher (year 2018)

	Lower	Average	Higher
Central & Southern Asia	Afghanistan 46.24	62.55	Kyrgyz Republic 70.33
Europe & North America	Bosnia and Herzegovina 67.31	75.92	Sweden 84.98
Latin America & Caribbean	Haiti 49.16	66.26	Costa Rica 73.15
Northern Africa & Western Asia	Yemen, Rep. 45.66	63.62	Israel 71.85
Australia and New Zealand (1)	Australia 72.89	75.37	New Zealand 77.86
Eastern and Southern-Eastern Asia	Myanmar 59.03	67.54	Japan 78.52
Sub-Saharan Africa	Central African Republic 37.66	52.85	Mauritius 64.68
World		*52.46*	

(1) This region only considers two countries Australia and New Zealand, as no more data is available.

Table 5 also confirms that several of the low performers can be associated with the impact of human-made disasters, particularly wars. This can be confirmed in Figure 3, which shows SDG2 scores in Northern Africa & Western Asia; countries with lower scores are or have been in war recently: Iraq, Sudan, Syria, and Yemen.

Figure 3. SDG2 scores in Northern Africa & Western Asia in 2018



Source: Own preparation

On the positive side, Table 6 also shows that there is a process of convergence. Model 1 suggests that less developed countries have a more accelerated progression than the more developed, as indicated by the comparison between the less and the more developed countries' mean slopes. The same convergence is shown within the regions, as the less developed countries have a higher mean slope.

Table 6. Countries' intercepts and slopes from Model 1 (Unconditional model).
Lower and higher per region (year 2018)

Region	Lower		Higher	
	Intercept	Slope	Intercept	Slope
Central & Southern Asia	Kazakhstan		Afghanistan	
	1.800	0.037	1.558	0.126
Europe & North America	Sweden		Bosnia and Herzegovina	
	1.929	-0.007	1.780	0.048
Latin America & Caribbean	Uruguay		Haiti	
	1.826	0.028	1.547	0.142
Northern Africa & Western Asia	Israel		Yemen	
	1.855	0.002	1.569	0.108
Eastern & Southern-Eastern Asia	Singapore		Cambodia	
	1.858	0.014	1.660	0.107
Sub-Saharan Africa	Mauritius		Central African Republic	
	1.775	0.037	1.416	0.174
World (average)	*Intercept*	*1.752*	*Slope*	*0.055*

Note: Since they are logarithms, the coefficients are interpreted as elasticities or percentage changes.

As indicated above, the speed of such convergence can be tripled through sustainable international logistics strategies and practices, but to increase their effectiveness, and considering the noticeable differences between regions, to close the gap between the richest and the poorest regions, demands using *ad hoc* regional policies. However, the question is where these regional sustainable logistics strategies should focus, as six different criteria can be targeted: customs, infrastructure, international shipments, service quality/logistics competence, timeliness, and tracing and tracking.

To decide where to implement regional sustainable logistics strategies, one source of valuable information comes from the experiences of the logistics professionals around the world; those who participated in evaluating the Logistics Performance Index (LPI) components for their countries. A finding is that independently from which is the country of origin of these professionals there is consensus that the most impactful LPI component is 'Customs' (see Table 7). Other components depend on regional contexts. For instance, 'Infrastructure' seems to be an issue of concern in countries located in less developed regions (i.e., Central and Southern Asia, and Sub-Saharan Africa). Conversely, for richer countries, the logistics professionals' concerns are linked to the cost of 'International Shipments'. Therefore, if there is an interest in improving SDG2 performance, what logistics

professionals would recommend is to improve how customs work around the world. This view coincides with the World Bank's opinion concerning soft reforms to facilitate trade flows, as these provide higher and quicker returns on investment than hard infrastructure (World Bank, 2018). However, public investment must continue to improve international logistics infrastructure in areas where it is underdeveloped.

Furthermore, according to the World Bank (2018), the most successful international logistics combo includes policy perspectives (new regulations), trade easiness, and trade and investment planning; in other words, countries that implement far-reaching changes seem to be those that incorporate international logistics as an integral part of their economy. Moreover, something common among the top performers is the use of interagency coordination and strong public–private dialogue.

Table 7. Performance comparison by LPI component and regional location

Relevance per region	customs	infrastructure	logistics competence	International shipments	tracking tracing	timeliness
Central and Southern Asia	**2.35**	**2.35**	2.49	2.46	2.59	2.96
Central Asia	2.36	2.38	2.43	2.39	2.60	3.04
Southern Asia	2.34	2.33	2.52	2.49	2.58	2.90
Europe and Northern America	**3.19**	3.32	3.39	3.28	3.44	3.78
Europe	3.17	3.29	3.37	3.27	3.42	3.76
Eastern Europe	2.77	2.81	3.01	3.06	3.06	3.51
Northern Europe	3.42	3.52	3.56	3.31	3.65	3.90
Southern Europe	2.94	3.02	3.09	3.15	3.14	3.58
Western Europe	3.73	4.06	4.03	3.69	4.02	4.23
Northern America	3.69	3.90	3.89	3.44	3.95	4.02
Latin America and the Caribbean	**2.46**	2.47	2.61	2.70	2.69	3.06
Caribbean	2.26	2.21	2.33	2.43	2.38	2.64
Central America	2.49	2.57	2.77	2.82	2.82	3.22
South America	2.53	2.54	2.65	2.76	2.76	3.16
Northern Africa and Western Asia	**2.60**	2.77	2.73	2.80	2.85	3.23
Northern Africa	2.36	2.44	2.50	2.56	2.68	3.02
Western Asia	2.66	2.86	2.79	2.86	2.89	3.28
Oceania *	3.79	3.98	3.86	3.34	3.87	4.12
Eastern and Southern-Eastern Asia	**2.93**	3.03	3.15	3.13	3.21	3.53
Eastern Asia	3.23	3.46	3.37	3.24	3.39	3.77
Southern-Eastern Asia	2.80	2.84	3.05	3.09	3.13	3.43
Sub-Saharan Africa	2.26	**2.24**	2.37	2.50	2.50	2.80

Note: Likert scale from "very low" (1) to "very high" (5)

** Oceania only considers Australia and New Zealand. No data is available for the rest of the countries.*

Table 7 can be interpreted as what is the expected agenda for improvements that logistics professionals in each region/subregion of the world would like to see implemented. However, we must recognize that the effects of economic and social turmoil and the effects of unexpected events, such as COVID-19 and human-made disasters could affect the future views of logistics professionals. Nevertheless, challenges to improving international logistics performance are substantial. The World Economic Forum (n.d.) proposes to pay attention to a set of supply chain megatrends, such as the digitalization of supply chains, restructuring global value chains, supply chain sustainability, logistics skills shortages, logistics property and infrastructure, supply risk and recovery, and e-commerce and demand chains.

Even though Table 7 suggests a consensus concerning 'Customs', there are some challenges difficult to remove from customs operations (Chibira, 2021). For instance, customs procedures are different depending on each country, and some are unclear. This becomes exacerbated as few countries have an effective customs management integration; digital technologies and staff with adequate skills are not easily accessible. Furthermore, the incorrect classification of goods imported and errors in tariff classifications increase the time taken to complete and approve import documentation. Additionally, false invoices and under-invoicing demand extra efforts in terms of documentation, physical inspections, and controls. Finally, international logistics usually suffers from asynchronous operations as trading partners may operate in different time zones. To alleviate the impact of such challenges. the International Trade Centre (2018) suggests the use of facilitation agreements, such as the authorized operator scheme, which might involve at least three of the following measures: (a) low documentary and data requirements; (b) low rate of physical inspections and examinations; (c) rapid release time; (d) deferred payment of duties, taxes, fees, and charges; (e) use of comprehensive guarantees or reduced guarantees; (f) a single customs declaration for all imports or exports in a given period, and (g) clearance of goods at the premises of the authorized operator or another place authorized by customs. However, custom bottlenecks are not easy to remove. Initiatives for facilitating flows usually face weak institutional structures; lack of transparency; corruption and underhand payments; the presence of actors that benefit from the existence of chaos at border posts, and not every country demonstrates political will and commitment (Chibira, 2021).

The second element to consider from Table 7 depends on each country's level of development. Northern and Western Europe, Northern America, Australia and New Zealand, and Eastern Asia are more concerned with the cost of 'International Shipments', whilst the less developed countries would prefer an improvement in terms of 'Infrastructure'. In highly integrated economies like the EU, significant increases in transport costs are not expected; this may be due to the simplification achieved in international business procedures within the region and with similar economies, and the benefits

due to extensive integrated communication networks. Conversely, less developed countries are in a stage where infrastructure limits their capabilities to conduct frictionless international exchanges.

Furthermore, independently from the region where each country lies, there seems to be a global consensus that 'Logistics competence' is an area that requires further improvement. Some traditional approaches involve the development of human capital through education and training, and multi-stakeholder collaboration to harmonize competency standards to raise skill levels in private and state-owned logistics (World Bank, 2018).

According to the views of global logistics professionals, even though 'Tracking and tracing' might be an element that demands attention, it is not at the top of the improvement agenda anywhere in the world. In their view, other issues concerning logistics are more urgent to improve. This does not mean that efforts related to incorporating ICTs to safely distribute products in a global market are not important. Indeed, a recent study highlighted the potential that novel technologies, such as the Internet of Things, blockchain, robotics, and automation can have on food logistics, in terms of bringing transparency, swift delivery of food at a reduced cost, flexibility, and capability to deliver the right quality product at the right place and at the right time (Jagtap *et al.*, 2021). In light of our findings, it is suggested that as other elements of LPI improve, tracking and tracing will earn major relevance, in the future.

Finally, 'Timeliness' seems to be the best-rated LPI component (see Table 7). This may imply that having short delivery times is considered a threshold capability (Johnson *et al.*, 2014). Many companies seem to be able to deliver very fast, so not having such a capability may destroy the business, rather than provide a competitive advantage. Nevertheless, timeliness can be achieved by different methods, such as more effective customs services, better infrastructure, tracking and tracing, logistics competence, or shipment pricing. Where to focus is a case-by-case decision, but it should involve the design, execution, and development of national and regional programs, particularly those concerning big international infrastructure projects.

7. Conclusions

This study investigated the link between international logistics performance and the UN Sustainable Development Goal 2. Logistics, though critical for food availability, and therefore the achievement of lower levels of hunger and higher levels of food security, is seldom incorporated in studies related to the advancement of SDG2, Zero Hunger. Specifically, using mixed-effects regression, this paper shows that international logistics performance has a strong predictive capability for SDG2. This means that efforts towards the achievement of SDG, and associated targets, depend on an improvement of logistics performance to a certain extent. Such improvements would likely involve changes to one or more of

the LPI dimensions, including customs, infrastructure, international shipments, service quality/logistics competence, timeliness, and tracing and tracking. Therefore, efforts to be promoted by both the public and private sectors regarding an improvement in logistics performance could also support the achievement of SDG2 and associated targets, such as food security and sustainable food production.

As global supply chains are becoming more complex, international logistics performance is earning a more relevant role in achieving reliable supply chains and predictable service delivery for traders (World Bank, 2018). However, as illustrated in the previous section, challenges to improving international logistics performance are substantial and vary among different regions of the world. Improving logistics performance to achieve SDG2 will likely require new and extensive investments. It is hoped that this study provides a better understanding of the priority areas in specific countries and regions to help policymakers promote Zero Hunger.

7.1 Implications for policy and practice.

Considering the LPI's strong predictive capability for SDG2, this study proposes an agenda for LPI improvements based on the views of logistics professionals in each region/subregion of the world, which can assist regional policymakers striving to achieve SDG2. According to logistics professionals around the world, the LPI dimensions related to public policies ('Customs', 'Infrastructure', and 'Logistics competence') require more urgent actions for improvements than the LPI dimensions related to service delivery ('International shipment', 'Tracking and tracing', and 'Timeliness'). Particularly, there is global consensus that the most impactful LPI component is 'Customs', which needs improvement across all the regions of the world. Priorities also seem to vary depending on the region. 'Infrastructure' seems to be an issue of more concern in countries located in less developed regions. Conversely, for more developed countries the logistics professionals' concerns are linked to the cost of 'International Shipments'. Furthermore, independently from the region where each country lies, there seems to be a global consensus that 'Logistics competence' is an area that requires further improvement. Lastly, even though 'Tracking and tracing' might be an element that demands attention, it is not at the top of the improvement agenda anywhere in the world, as other LPI dimensions require more urgent attention.

7.2 Contribution to theory.

This study contributes to filling a gap in the supply chain management literature by providing evidence regarding LPI's strong predictive capability for SDG2. This is a first step towards recognizing the vital role that logistics performance can play in achieving Zero Hunger. Furthermore, the study proposes a logistics performance improvement agenda based on the needs of different regions of the world. Results presented here point to the need to consider specific regional needs when developing and implementing strategies for the improvement of logistics performance and the LPI-associated

dimensions. Based on the evidence provided here, the next obvious step for future researchers would be to investigate the specific aspects of the LPI dimensions, namely customs, infrastructure, international shipments, service quality/logistics competence, timeliness, and tracing and tracking, that need to be addressed at regional and country levels to improve overall logistics performance and SDG2.

Additionally, recent studies have identified strong synergies between SDG2 and other SDGs (Blesh *et al.*, 2019; Valin *et al.*, 2021). SDG2 has clear interactions with other goals, particularly SDG 1 (poverty eradication), SDG 3 (health promotion), SDG 4 (high-quality education for all), SDG 7 (clean energy), SDG 11 (sustainable cities), SDG 12 (sustainable consumption, including halving food waste), SDG 13 (climate action), and SDG 15 (sustainable forest management) (Atukunda *et al.*, 2021). This points to the need to investigate the indirect or direct impact that logistics performance could have on other SDGs. This would provide opportunities to create synergies to boost SDG2 actions, or even avoid undermining efforts towards the achievement of other SDGs.

7.3 Limitations.

The present study has some limitations that could be addressed by further research. The use of LPI scores is not fully free of critiques, as these scores are based on a web-based survey that aggregates the opinions of the worldwide logistics and freight-forwarding community. The World Bank (2018) identified limitations for this exercise. The effects of such limitations have been mitigated using a selection procedure of countries, and the use of a principal component analysis (PCA) to reduce the dimensionality from six indicators (i.e., customs, infrastructure, service quality, international shipments, tracking and tracing, and timeliness) into one (the LPI score), by a weighted averaging the six normalized scores. Additionally, it is important to notice that the data used in this study refers to 2018, a year before the COVID-19 pandemic began to impact global and local food supply chains. A new Logistics Performance Index (LPI) was expected to be conducted in 2020, but this was not the case, for obvious reasons. A comparison between before and after the COVID-19 pandemic would be relevant when new data is collected and made available. Changes in the logistics professionals' perceptions are expected, due to the pandemic effects on global logistics operations.

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9. Declarations

The authors declared that they have no conflict of interest.

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11. Appendix

Table 8. Countries excluded from the analysis

No LPI Score available		No SDG2 Score available	
Antigua and Barbuda	Nicaragua	Andorra	Micronesia, Fed. States
Azerbaijan	North Macedonia	Antigua and Barbuda	Monaco
Barbados	Palau	Bahamas, The	Nauru
Belize	Samoa	Barbados	Palau
Botswana	San Marino	Brunei Darussalam	Papua New Guinea
Cabo Verde	São Tomé and Principe	Comoros	Samoa
Dominica	Seychelles	Dominica	San Marino
Ethiopia	South Sudan	Equatorial Guinea	São Tomé and Principe
Grenada	St. Kitts and Nevis	Eritrea	Seychelles
Kiribati	St. Lucia	Fiji	Solomon Islands
Korea, Dem. Rep.	St. Vincent and the Gren.	Grenada	Somalia
Liechtenstein	Suriname	Guinea-Bissau	South Sudan
Marshall Islands	Tanzania	Kiribati	
Micronesia, Fed. Sts.	Timor-Leste	Korea, Dem. Rep.	
Monaco	Tonga	Libya	
Mozambique	Tuvalu	Liechtenstein	
Namibia	Vanuatu	Maldives	
Nauru		Marshall Islands	