IS LOGISTICS MEDIATING THE RELATIONSHIP BETWEEN POLLUTION AND ECONOMIC COMPLEXITY?

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ABSTRACT
The aim of this research is to contribute to the literature in the field, filling the gap concerning how logistics impacts the relationship between pollution and economic complexity worldwide. Investigating the weights of the multiple dimensions of logistic performance appears very relevant and strengthens the literature in the field in terms of studies carried out in abnormal times that impact society and the economy at their core. From a methodological standpoint, this study uses a structural equations approach, revealing a complex mediating chain linking pollution with logistics performances. Our results show that logistics is a net contributor to pollution and further investment in supply chain green innovation is needed to achieve the objectives of green logistics.

KEYWORDS: *economic complexity, logistic performance, pollution, structural equations*.

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1 INTRODUCTION

According Cristea et al. (2013), transportation is responsible for one third of the total trade-related greenhouse gas emissions world-wide. Moreover, same study argues that, logistics accounts for 75 percent of greenhouse gases emissions, three time more than the emissions attributable to production (Cristea et al., 2013, pp. 153). The contribution of logistics to pollution has also increased due to a recent shift in production operations towards lean manufacturing and just in time techniques. These operations techniques necessitate increasing the frequency of replenishment and also are using faster, more polluting transportation modes (Constangioara, 2008). Also, in Europe, inter-regional trade and even international trade relies on highly polluting road transport because of the relatively short distances involved (Constangioara, 2008). Taking into consideration all these aspects, we argue that increasing the efficiency of logistics is paramount to mitigating logistics' contribution to pollution.
Furthermore, reducing greenhouse gases is at the heat of European long term Green Deal strategy. Decreasing emissions form transport is considered one of the major challenges in achieving the proposed climate neutrality within EU by 2050 (2050 Long Term Strategy, 2019). Implementing new CO2 emission standards for vehicles, smart traffic management and designing modern freight delivery methods are part of a "Smart Mobility" strategy (2050 Long Term Strategy, 2019) which would ensure the sustainable mobility objective of the European Green Deal strategy.
Besides logistics, McKinney & Company Report (2020) appreciates that the feasibility of European Green Deal depends on innovation and investments in green technologies. A circular economy action plan is necessary to progress towards a low-carbon and efficient economy. Structural changes

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are necessary to replace actual technologies with environmentally friendly ones, ensuring a qualitative leap in the development of economies within EU. Thus, increasing the economic complexity (EC) of economies within EU would also contribute to achieving the objectives of the European Green Deal Strategy.

This research contributes to the literature in the field, filling the gap concerning the relationship between pollution, EC and logistics' performance. To this end, present study is employing a structural equation approach to estimate the pollution - EC relationship. We are using in our estimation a dataset of 110 global observations, with variables measuring ECI, pollution and six dimensions of logistics performance.

Although important contributions have been made by existing studies in the field, we are striving to augment the approach of EC – pollution estimations by controlling for the logistics' performance. Following Tavasszy (2018), we are also questioning that, within the Logistics Performance Index (LPI), all components are equally important. Consequently, we propose a principal component analyze to estimate the weigh attributable to each component.

Present research has also important policy implications. As we are analyzing the factors contributing to reducing pollution, our results inform policymakers throughout the world on the net effect of logistics on pollutions.

This research is structured as follows: section 2 presents the existing literature in the field. section 3 considers the research framework, hypotheses and the data and methods employed in our study. Section 4 presents the results of our empirical estimation. Sections 5 concludes and proposes directions for further research.

2. LITERATURE REVIEW

2.1 Economic complexity

Economic complexity is as a measure of non-observable attributes of production, measuring a country`s productive knowledge and capabilities. Hidalgo et al. (2007) argue that EC is key to future economic growth, reducing income inequality and tackling the greenhouse gas emissions. He also has first presented a methodology for computing an Economic Complexity Index (ECI), which rests on a circular argument: (a) the complexity of a location depends on the economic activities present in it and (b) the complexity of an activity is dependent on the complexity of location where that activity is present (Hausman and Hidalgo, 2009). Thus, ECI is the solution to the simultaneous equations 1 and 2 (OEC, Methods):

$$K_c=f(M_{cp},g(M_{cp},K_c) \quad (1)$$

$$K_p=g(M_{cp},f(M_{cp},K_p) \quad (2)$$

where K_c is the complexity of a location, M_{cp} represents the activities in a location and K_p the complexity of an activity.

The vast majority of studies in the field compute EC indexes at national level. However, there are several exceptions to this. In particular Reynolds et al. (2017) have used a multi-regional input-output dataset computing EC indexes at regional level for Australia. Gau and Zhou (2017) also estimate the EC at regional level for China' provinces. Using both international and interstate trade flows, both for goods and services, the above-mentioned papers have documented that small differences in the productive knowledge have the potential to largely affect the relative industrial complexity at regional level. In their turn, Marco, Llano and Pérez-Balsalobre (2022) have used a sub-national level Spanish dataset to document the necessity of a "smart specialization of regions within countries" (pp. 11), a specialization built on the triple bottom line objectives of environmental, social costs and profits from growth.

Can and Gozgor (2017)and Neagu (2019) analyze the relationship between EC and environmental quality, measured by greenhouse gas emission. Can and Gozgor (2017) focused on the link between EC and carbon emissions in France, introducing EC in a model focused on testing the validity of environmental Kuznets curve. Neagu and Teodoru (2019) and Neagu (2019) have furthered the knowledge in the field, showing a negative linear relationship between EC and pollution within EU. This is somehow counter intuitive, as one would expect that pressures to increase the complexity of economies would lead to an increased energy consumption, which further would increase pollution. However, the relationship between pollution and economic complexity is dependent on complex factors, ranging from the differences on energy efficiency and energy mix composition (Neagu and Teodoru, 2019), to transport infrastructure, logistics mix, geography and even the prevalence of modern types of consumptions (Cristea et al., 2013). Furthermore, the road to increased economic complexity is associates with structural transformations of the economies. Diversification, specialization and sophistication of economies, corroborated with shifting the most polluting industries to less developed regions have resulted in production of highly complex output in low polluting industries and more developed economies or regions. Indeed, this line of reasoning is supported by the findings of Marco, Llano and Pérez-Balsalobre (2022) which shows that highly developed Spanish regions have already shifted their most polluting heavy industries to less developed surrounding regions. Not ultimately, as Aiginger (2014), Ashord and Renda (2016) and Neagu (2019) show, the negative relationship between EC and pollution is meaningful in the context of EU low-carbon strategy, which highlights the importance of decarbonization in the EU. Altogether, these arguments also support a negative relationship between EC and pollution.
However, there are also arguments in favor of a positive relationship between pollution and EC. As Cristea et al. (2013) and Constangioara (2008) show, share of pollution attributable to logistics activities in higher than the corresponding figure related to manufacturing. Moreover, advancements in operations technologies often work towards increasing pollution, as for example by means of more frequent replenishments. Taking into consideration all these information, additional empirical evidence is needed to analyze the relationship between pollution and EC.

2.2 Green logistics

A logistic performance index (LPI) was proposed in 2007 by the World Bank as a benchmarking tool available for assessing the logistics performance at international level. The LPI is a composite index, with six components: (a) customs, (b) quality of transport infrastructure, (c) reliability of delivery times, (d) tracking technology, (e) quality of logistics services and (f) pricing in international shipments (Tavasszy, 2018). LPI was subsequently accepted as a proxy for logistics performance at country level and employed in many empirical studies in the field (Jumadi and Zailani, 2010, Solakivi et al., 2014).
Each component of the LPI was found to influence significantly the overall logistics performance (Martí, Puertas, and García, 2014). There is also evidence that logistics performance at country level has a positive impact on global competitiveness (Ekici, Kabak and Ülengin, 2016). Moreover, Çemberci, Civelek and Canbolat (2015), found a complex chain of relationships between economic development and global competitiveness, with logistics' performance having a positive and statistically significant mediating effect.
Existing literature in the field argues that recent evolutions in the business environment have increased the importance of environmental considerations for the entire logistics sector (Murphy and Poist, 2003). Green supply management (GSCM) and green logistics incorporate the environmental initiatives into the traditional management of logistics flow at supply chain level. Among the specific action targeted, GSCM and green logistics deal with eco-design, green purchasing and mitigating the negative impact on environment of various logistics activities (Jumadi and Zailani, 2010, Rodrigue, Slack and Comtois, 2017). However, since transportation is a

major contributor to pollution as Cristea et al. (2013) shows, we might expect a negative impact of logistics on environment.

3. METHOD

3.1 Research framework

We rely on the work of Tavasszy (2018) to questions the assumption of equal weights attributable to the components of LPI. Consequently, we propose estimating the weights of LPI using a confirmatory factor analysis (CFA).

The estimated LPI obtained in the CFA analysis was subsequently employed in our mediation analysis. Based on Tavasszy (2018) and Poist (2003) we have acknowledged that green logistics is efficient in reducing the negative effects of logistics on environment. Furthermore, based on Cristea et al. (2013) and Marco, Llano and Pérez-Balsalobre (2022), we have acknowledged the link between EC and pollution. However, when considering the share of pollution attributable to logistics services, provided that complex products travel longer, it is possible that, on balance, both EC and logistics adds to pollution, in spite of the fact that rail or ships, which are the preferred transportations modes employed for long distances, are considered the cleanest modes of transport. Taking all these aspects into consideration, we appreciate that further research is needed to document the relationship between economic complexity, logistics and pollution. Consequently, in developing our research framework, we have proposed a complex chain of relationships linking economic complexity, logistics and pollution. This strategy is operationalized through a structural equations model (SEM). A SEM has the advantage of dealing with complex relationships as those proposed by present research. Even more relevant, a SEM allows us to investigate the mediating effects of logistics' performance on the relationship between EC and pollution.

Our proposed research framework is thereby depicted in fig.1.

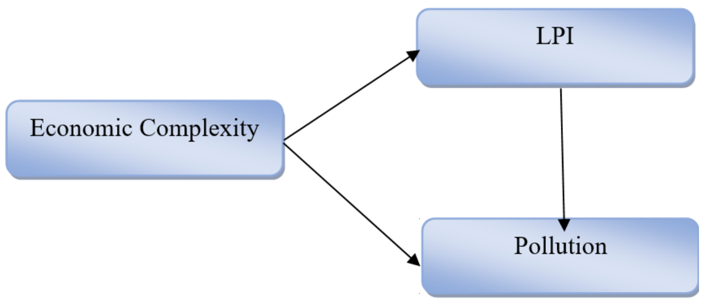

Figure 1. Proposed research framework

Source: authors

As fig. 1 shows, we propose using the LPI generated form our CFA analysis to investigate weather LPI has a mediating effect on the relationship between EC and pollution.

3.2 Research hypothesis development

Based on the work of Tavasszy (2018) and Poist (2003) we formulate our first research hypothesis:

H_1: The relationship between EC and pollution is negatively mediated by logistics performance;

Following Cristea et al. (2013) and Perez-Balsalobre et al. (2019, 2020) we formulate our second research hypothesis:

H_2: Economic complexity is negatively related to pollution;

3.3 Data

The proposed empirical research uses a global dataset with 110 observations at country level. The components of LPI index were obtained from Wordbank dataset (https://lpi.worldbank.org/international/aggregated-ranking). The ECI was obtained from the Atlas of Economic Complexity database (https://atlas.cid.harvard.edu/rankings). As proxy for pollution, we have used net greenhouse gas emissions in kt. of CO2 equivalent from the World Bank data (https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE). Data was collected for a single year (2018). Summary statistics of the variables employed in the analysis is presented in table 1.

Table 1. Summary statistics

Variable	Label	N	Mean	Std Dev	Minimum	Maximum
I	Transport infrastructure	110	2.835	0.678	1.556	4.374
IS	Pricing in international shipment	110	2.928	0.508	1.989	3.995
LS	Logistics quality and competence	110	2.913	0.618	1.883	4.311
TT	Tracking and Tracing	110	3.004	0.625	1.636	4.323
T	Timeliness	110	3.356	0.554	2.037	4.410
C	Customs	110	3.356	0.554	2.037	4.410
ECI	Economic complexity index	110	0.051	0.975	-1.839	2.480
ghg	Greenhouse gases (kt. of CO2 equivalent)	110	305098	1232722	2070	12471090
lghg	ln(ghg)	110	11.237	1.459	7.635	16.339

Source: authors

3.4 Methodology

Our CFA analysis is meant to estimate an overall LPI as a proxy for logistics performance. The LPI is a first order latent construct, with six dimensions: customs, transport infrastructure, delivery times, tracking technology, logistics services and pricing in international shipments. As required by Kline (2011), we have assessed the indicator reliability, convergent reliability, internal consistency and discriminant validity of the constructs employed in the analysis. In the second stage, in order to test our research hypothesis, we have chosen a SEM approach because it is best suited for analyzing a complex research framework (Hu and Bentler, 1998). R statistical package was employed for our analysis. Robust standard errors have been reported for CFA estimations and for direct path coefficients of SEM model. However, the statistical significance for the indirect coefficient of interest is estimated through bootstrapping. Confidence interval is reported in this case.

4. RESULTS

4.1 Measurement model assesment

We use Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), The Root Mean Square Error of Approximation (RMSEA) and Standardized Root Mean Squared Residual (SRMR) to assess the overall fit of our CFA model. According to Hu and Bentler (1998) and Henseler et al. (2014), the threshold values are 0.08 for SRMR, 0.05 for RMSEA and 0.95 for CFI and TLI. In our case, CFI and TLI are both 0.99, RMSEA is 0.030, SRMR is 0.006. Consequently, all indices are indicating a good fit. Additionally, our model is explaining 93.6% of the variation in I (Transport infrastructure), 83.9% of the variation in IS (Pricing in international shipment), 99% for LS (Logistics quality and competence), 91.8 for T (Timeliness) and 91.5 for C (Customs).

The results of the exploratory model shows that all factor loadings are well above the 0.5 threshold required for the indicator reliability condition (Hulland, 1999). In addition, all outer loadings are highly statistically significant (p =0.000). All items used to measure our constructs are a good measurement of the respective construct. The Cronbach's alpha is above the 0.7 threshold value.

Table 2. Factor loadings

Loadings	Std Estimate	Std. Err.	p-values)	Cronbach's Alpha	Average Variance Extracted (AVE)
Transport infrastructure	0.968	0.047	0.000	0.921	0.835
Pricing in international shipment	0.916	0.037	0.000		
Logistics quality and competence	0.995	0.042	0.000		
Tracking and Tracing	0.958	0.044	0.000		
Timeliness	0.937	0.039	0.000		
Customs	0.957	0.041	0.000		

Table 3 offers us the estimates variances and their statistical significance.

Table 3. Variances

Variable label	Std Estimate	Std. Err.	p-values
Transport infrastructure	0.064	0.005	0.000
Pricing in international shipment	0.161	0.006	0.000
Logistics quality and competence	0.01	0.002	0.054
Tracking and Tracing	0.082	0.005	0.000
Timeliness	0.122	0.005	0.000
Customs	0.085	0.004	0.000

All the estimated variances are statistically significant, although for LS we have only a 10% significance level. Our CFA model can be represented as shown in fig. 2.

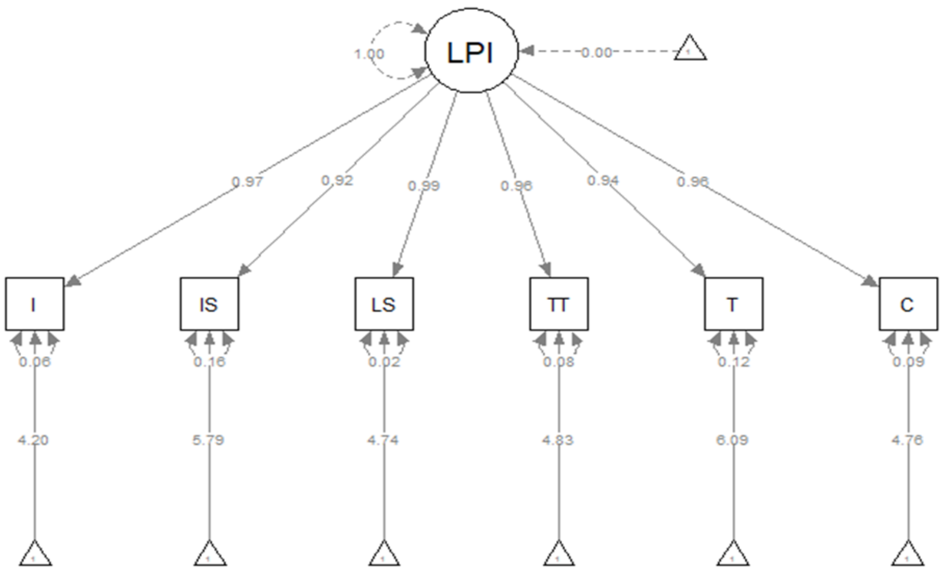

Figure 2. CFA results

All items presented in fig. 2 are also reported in tables 2 and 3.

4.2 Results of the structural analysis

In the case of the structural model, CFI is 0.986, TLI is 0.981, RMSEA is 0.042 and SRMR is 0.019, indicating a good fit.

Table 4. Direct effects

Path	Std Beta	Std Error	p-values
lghg ~ LPI	0.55	0.106	0.000
LPI ~ ECI	0.806	0.155	0.000
lghg ~ ECI	-0.129	0.209	0.078

As expected, all direct effects are statistically significant. However, the estimate corresponding to ECI is significant only at 10% significance level. Table 4 also shows that the direct effect of LPI on pollution is positive. Also, we see that the mediating effect of LPI on the relationship between ECI and pollution is positive and statistically significant (table 5).

Table 5. Mediation effect

Path	Std Beta	Std Error	p-values	ci.lower	ci.upper
Lghg~ECI*LPI	0.443	0.151	0.000	0.370	0.952

R statistical package uses bootstrapping for assessing the statistical significance of indirect path coefficients. For the bootstrapping analysis we have set the number of samples employed to 1000, as recommended by Hair, Hult, Ringle and Sarstedt (2017). As recommended by existing SEM literature, we have also computed the confidence intervals for the estimated indirect effect. We see that both the lower limit and the upper limit if the confidence interval are positive, which is consistent with a significant indirect effect of logistics' performance on the relationship between pollution and EC.

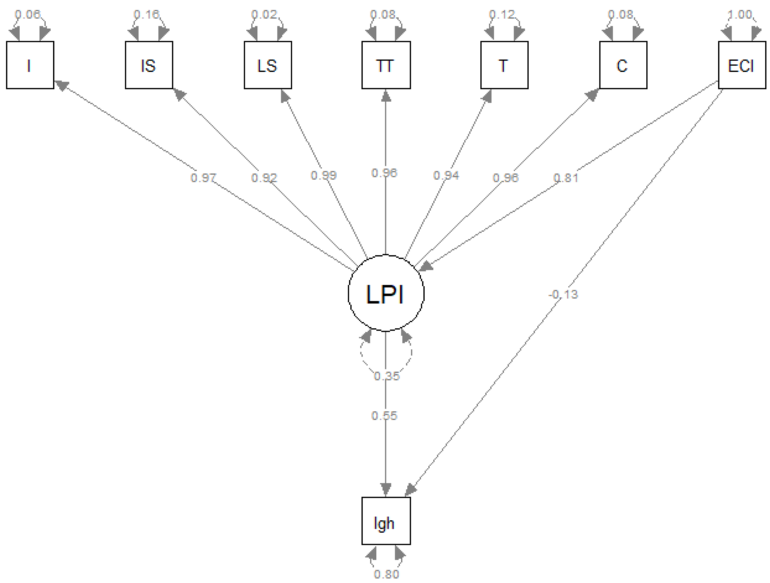

Figure 3. Results of the SEM estimation
Source:

Figure 3 summarizes the results of our SEM estimaton. We see that, while EC is successfully reducing pollution, logistics adds to it. Support for our research hypotheis is summarized in Table 6.

Table 6. Support for research hypothesis

	Path	Std Beta	Std Error	Decision
H_1: The relationship between EC and pollution is negatively mediated by logistics performance	lghg ~ ECI	0.443***	0.151	Reject
H_2: Economic complexity is negatively related to pollution;	Lghg~ECI*LPI	-0.129***	0.209	Support

Note:*p<0.1, **p<0.05, ***p<0.01

5. CONCLUSIONS

As indicated in table 6, empirical results do support our research hypothesis that economic complexity is contributing to reducing pollution. Similar results have been reported in existing studies in the field. As Marco, Llano and Pérez-Balsalobre (2022), Neagu(2019) and Ashord and Renda (2016) argue, economic complexity is associated with structural changes in economies, with high complexity products being produced with low polluting industries. We have to acknowledge that, at the same time, this result is worrying for less - developed economies, which have to deal with the externalization of polluting industries from richer countries, as Lieb (2003) has pointed out. We have also documented that logistics mediates the relationship between EC and pollution. However, the relationship between EC and pollution is strengthen by LPI. Indeed, Cristea et al. (2013) have shown that, when complex products travel longer, it is possible that, on balance, EC adds to pollution, A positive mediation effect of logistics is also supported by the recent shift in production operations towards lean manufacturing and just in time techniques which necessitate increasing the frequency of replenishment and are using faster, more polluting transportation modes (Constangioara, 2017). Also, in Europe and Japan, inter-regional trade and even international trade relies on highly polluting road transport because of the relatively short distances involved (Constangioara, 2017).

A positive mediation effect of logistics is also stressed out by Mc Kinsey & Company, (2020). According to the above - mentioned report, it will take some ten years to set up green supply chains necessary to achieve the objectives set by the EU' Smart Mobility strategy. Reducing greenhouse gas emissions related to transportation services is possible, although larger ships and aircrafts, travelling longer distances, are still expected to rely on fossil fuels (Mc Kinsey & Company, 2020).

As our study has documented that ECI is negatively associated with pollution (table 4), we conclude that achieving green logistics' objectives is possible only through EC channel. Thus, further investment in green innovation and collaboration of supply chain members will positively contribute to EC and will reduce greenhouse gas emissions attributable to logistics, as anticipated by Tavasszy (2018).

We intend to further analyze whether the mediation effect of logistics on the relationship between EC and pollution becomes negative. A longitudinal study would allow us to employ a dynamic panel approach to our estimation. A continuation of our study would allow us to better document the feasibility of EU' Green Deal Strategy.

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