Metropolitan governance and environmental outcomes: does inter-municipal cooperation make a difference?

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ABSTRACT

Inter-municipal cooperation in metropolitan areas has been previously shown to save costs, but can it also improve environmental outcomes? The existing empirical evidence is largely based on single case studies and does not allow to ascertain the net effect of cooperation. We develop a three-level mixed-effects linear model to conduct a systematic large-n study testing the impact of cooperation in transportation on CO_2 transport emissions. We use a novel dataset covering over 200 metropolitan areas in 16 OECD countries. The findings demonstrate that both fragmented and consolidated metropolitan governance structures are equally inefficient in delivering a reduction in CO_2 transport emissions. Further, without functional enforcement mechanisms, mitigation policies fail to have a positive effect on environmental outcomes. Inter-municipal cooperation in metropolitan areas facilitates coherence and widespread enforcement and emerges as a crucial factor explaining the reduction of CO_2 transport emissions. Effects of metropolitan cooperation on transportation are magnified by the presence of national environmental mitigation policies.

KEYWORDS Metropolitan areas; inter-municipal cooperation; CO_2 transport emissions; OECD; environmental outcomes

1. Introduction

As global efforts are yet to lead to effective environmental treaties, countries rely on national and subnational policies to address environmental challenges (Butterfield and Low 2016; Ostrom 2010). In that regard, the metropolitan scale has emerged as salient for environmental policy interventions (Andresson 2015; Koch 2013; McGuirk et al. 2015; Parnell 2016). Metropolitan areas represent a significant source of environmental problems worldwide. They are responsible for about 60% of the world’s global energy consumption, 70% of global greenhouse gas emissions, and 70% of global waste (UN-Habitat 2016).

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Addressing environmental issues in metropolitan areas poses a collective action problem due to the indivisibility of environmental outcomes (Jagers et al. 2020), low incentives for cooperation, and the high risk of freeriding. To find joint solutions to cross-boundary problems, local governments in metropolitan areas have to cooperate but are unlikely to do so voluntarily (Ostrom 2010). Besides coercion (Brennan 2009; Carraro 2003; Wiener 2007), local governments may be incentivised to enter inter-municipal cooperation if it is likely to yield benefits. Such incentives in metropolitan governance can be seen as a quest for better service delivery outcomes (Ahrend & Schumann, 2014; Andersson 2013, 2015; Germà Bel and Warner 2015). This includes better economic and environmental outcomes.

Studies on the economic efficiency of cooperation are predominant in the literature. Empirical evidence shows that inter-municipal cooperation saves costs (Germa Bel, Fageda, and Mur 2014; Blaeschke and Haug 2018; Dijkgraaf and Gradus 2003; Sorensen 2008; Soukopová and Vaceková 2018; Zafra-Gomez et al. 2013) but does it also improve environmental outcomes? This study tests the impact of inter-municipal cooperation on environmental outcomes in metropolitan areas using a three-level mixed-effects linear model and a novel dataset covering 229 metropolitan areas in 16 OECD countries (see Appendix A).

In what follows, we review the literature on the relationship between cooperation and environmental outcomes and introduce the mechanisms through which cooperation can be expected to impact CO$_2$ transport emissions. Section 3 explains the methodology adopted to test the relationship. In Sections 4 and 5, we present the data used and explain the estimation method respectively. In Section 6 we discuss the results of the estimation and finally, Section 7 concludes with a highlight on limitations and areas for further studies.

2. Inter-municipal cooperation and environmental outcomes

Environmental problems and outcomes are not divisible, and they spill beyond territorial boundaries. Local governments in metropolitan areas, driven by varied interests and priorities, face a collective action problem when they have to address environmental issues jointly. To overcome the lack of inherent incentives to cooperate and achieve a reduction in negative environmental outcomes, governance interventions will require cooperation among local governments within a metropolitan area (Frederickson and O’Leary 2014; Lemos and Agrawal 2006; Nelles 2010; Nicholls 2005; Pricen 2003)
In this paper, inter-municipal cooperation refers to instances where local governments in a metropolitan area enter a formal or informal agreement to work together on a policy issue. Cooperation is treated as a binary outcome. Metropolitan local governments working together on either one or more transport-related issues are considered to be engaged in cooperation on transportation. This cooperation could be for infrastructure provision, service provision, policy, regulations, among others. Conversely, non-cooperation is indicated when local governments do not work together on transportation issues.

The paper uses CO₂ transport emissions as a proxy for environmental outcomes. The focus on transport is justified because it represents a major contributor to CO₂ emissions (Mustapa and Bekhet 2015; Timilsina and Shrestha 2009), and a reduction in transport sector CO₂ emissions is an imperative worldwide agenda for overall CO₂ mitigation (Ding et al. 2013).

This paper posits that inter-municipal cooperation reduces CO₂ transport emissions. Cooperation facilitates the uniformity of policy action and the economy of scale effects in enforcing environmental mitigation efforts (LaBelle 2012). By contrast, non-cooperation is likely to penalise unilateral efforts and lead to inefficient outcomes. For instance, the use of CO₂ emission taxes as a policy response to climate change resulted in cross-border differentials and a significant increase in demand for gasoline in neighbouring regions with lower prices (Banfi, Filippini, and Hunt 2005; Romero-Jordán, García-Inés, & García, 2013).

The existing evidence to the positive impact of joint environmental policy interventions on transport-related environmental outcomes in metropolitan areas is largely based on single case studies (see Martínez-Jaramillo et al., 2016; Pacheco et al. 2017; TFL 2014; Wang et al. 2017) and thus have limited external validity. A systematic large-n study is needed to establish the net effect of inter-municipal cooperation on environmental outcomes. This paper fills this gap by investigating cooperation effects across more than 200 metropolitan areas in 16 OECD states.

3. The conceptual mechanisms: cooperation and CO₂ transport emissions

The state of CO₂ transport emissions in a metropolitan area is affected by a wide range of factors. Various studies have established direct determinants of CO₂ transport emissions to include economic, socio-cultural, technological, and geographical factors (see Lakshmanan and Han 1997; Lu, Lin, and Lewis 2007; Mustapa and Bekhet 2015; Schipper 1995; Schipper and Marie-Lilliu 1999; Scholl, Schipper, and Kiang 1996; Timilsina and Shrestha 2009). The effects of these direct determinants, however, can be either positive or negative, depending on how they are governed (Khan 2013; Lemos and
Agrawal 2006; Timilsina and Shrestha 2009). Governance-related determinants of CO₂ transport emissions concern mitigation measures and enforcement mechanisms, which can, in turn, be amplified or undermined by the metropolitan structure and whether or not individual municipalities cooperate on the relevant policies. In what follows, we put forward our expectations regarding the anticipated impact of, first, the direct determinants and, second, governance-related factors on CO₂ transport emissions outcomes.

The expectations regarding the impact of economic factors are twofold. On the one hand, due to their higher capacity to adopt and enforce environmental policies, richer countries, as well as metropolitan areas located in these countries, can be expected to be better suited than poorer countries to address environmental issues (Levinson, 2105). For instance, plans to ban fossil fuel combustion engines are still predominantly found in rich economies (Lutsey 2015) and globally, 95% of electric cars are sold in only 10 countries: China, the US, Japan, Canada, Norway, the U.K., France, Germany, the Netherlands, and Sweden (OECD & IEA, 2017). On the other hand, economic growth itself presents a principal factor driving higher transport sector CO₂ emissions (Timilsina and Shrestha 2009; Bel and Rosell 2017). The richer people get, the more they tend to prefer the use of private vehicles rather than public transportation, which is less environmentally efficient.

From the socio-cultural perspective, population size, distribution and individual preferences for a specific transportation mode and frequency of travel can be a behavioural issue. For example, Schipper (1995) finds that the differences between the United States and the European countries’ automobile and energy consumption arise from the differences in total transport activity and the mode of transport used. While it is ideal to drive a private car in the United States, other transport modes like buses and bicycles are common in many European countries. Generally, lower frequency of travel, the use of public and non-motorised transportation modes reduces CO₂ transport emissions.

Further, technological advancement is expected to reduce CO₂ transport emissions through the adoption and promotion of clean energy and reduction of energy intensity. However, these positive effects depend on pro-environmental policy interventions and investments.

Finally, total land size as a geographical determinant can be expected to affect the outcome of CO₂ transport emissions. Larger metropolitan areas are likely to produce more CO₂ transport emissions due to increased traffic and longer travel distances (Schipper 1995). However, the scale of this effect depends on whether the metropolitan spatial planning is compact or sprawl oriented.
With the exception of the geographical form of a metropolitan area, which is fixed, CO₂ transport emissions and their direct determinants can be expected to vary over time and be influenced by country-level factors. For instance, we expect a metropolitan area’s budgetary base to include significant contributions from national allocations. Likewise, national legislation may dictate the level of autonomy that metropolitan governments have in decision making. We expect the extent of the impact that the direct determinants and governance measures have on CO₂ transport emissions to vary from one metropolitan area to another. This variation could be due to the differences in initial conditions and the fact that metropolitan areas introduce different interventions that target environmental outcomes (Reckien et al. 2018).

To reduce CO₂ transport emissions, metropolitan and national governments can introduce an array of mitigation measures – that is, environmental interventions including regulations, directives, and actions aimed to alleviate the negative impact of their direct determinants. For instance, metropolitan governments can shape preferences for the mode of transportation in favour of environmentally friendly or sustainable transport. Likewise, through appropriate economic policies, they can channel economic growth towards investment in greener technologies. Governance efforts can also be directed to ease geographical dictates for extensive automobile use by promoting compact rather than sprawl-oriented spatial planning. Enforcement is required for the mitigation policies to be effective, and it can take the shape of either de jure measures such as legal provisions or de facto actions such as sanctions.

The mitigation policies and enforcement are expected to be more effective if local governments in a metropolitan area cooperate. This is because cooperation facilitates economies of scale (Niaounakis and Blank 2017) by enabling uniformity of the mitigation policies and a larger scale uptake through enforcement. Thus cooperation curbs freeriding (Bergholz 2018) and disincentivise a race to the bottom scenario in setting environmental standards (Engel 1997). As institutions and policies tend to be more effective over time, the effect of the governance measures on CO₂ transport emissions is expected to vary as appreciable levels of stability and certainty in operations are achieved (North 1994; Przeworski 2004).

Lastly, effective inter-municipal cooperation can be facilitated by the design of the metropolitan structure. The design could be a consolidated structure in which a centralised authority co-ordinates cooperation among the local governments or a fragmented structure whereby cooperation evolves voluntarily among the local authorities that retain independence (see Morcol and Zimmermann 2006; Sellers and Hoffmann-Martínó 2009; Visser 2002). We test whether a fragmented or consolidated metropolitan structure facilitates cooperation better. Figure 1 depicts the mechanisms through which cooperation has an impact on CO₂ transport emissions.
4. Data

To test the relationship between cooperation and CO₂ transport emissions, we use panel data covering 229 metropolitan areas in 16 OECD countries and three years (2000, 2005, and 2008) of observation (see Table 1 for descriptive statistics). We apply a three-level mixed-effects linear model as the estimation method.

At level 1 (year of observation), we capture the three years of CO₂ transport emissions observation reported in the OECD metropolitan governance database (OECD 2017).

At level 2 (metropolitan level), the main independent variable, cooperation, is obtained from the OECD Metropolitan Governance Survey (Ahrend, Gamper, and Schumann 2014). The control variables are sourced from the OECD metropolitan governance database (see Appendix B for a detailed description of the variables used). These include metropolitan area’s GDP as a proxy for economic determinants with population size and distribution proxied as territorial fragmentation for socio-cultural factors. Geographical factors are accounted for with total land area. Public transport authority is our proxy for mitigation policy, and
legislative, regulatory powers and likelihood of enforcement stand for enforcement. Metropolitan structure is measured as consolidated or fragmented.

At level 3 (country level), control variables are introduced to account for the embeddedness of metropolitan areas in their respective countries. For economic factors at the country level, we use country GDP from the World Bank databank (World Bank 2017). Socio-cultural factors – modal split and propensity to travel – are generated using total inland passenger transport from the metropolitan governance database (OECD 2017). Technological determinants are proxied with transport energy intensity from the Enerdata database (World Energy Council 2016). Finally, environmental policy stringency from the metropolitan governance database (OECD 2017) is used as a proxy for enforcement along with the Regional Authority Index (RAI), which measures the autonomy of local governments (Hooghe et al. 2016).

Table 1. Variable overview.

| Variable                                      | Count | Mean  | SD    | Min   | Max   |
|-----------------------------------------------|-------|-------|-------|-------|-------|
| **Dependent variable**                        |       |       |       |       |       |
| CO₂ transport emissions (%)                  | 687   | 3.26  | 5.84  | 0.1   | 41.8  |
| **Level 1 (Year of observation)**            |       |       |       |       |       |
| Independent variable                         |       |       |       |       |       |
| Year                                          | 687   | 1     | 0.82  | 0     | 2     |
| **Level 2 (Metropolitan level)**              |       |       |       |       |       |
| Main independent variable                    |       |       |       |       |       |
| Cooperation                                   | 229   | 0.50  | 0.50  | 0     | 1     |
| Metropolitan GDP*                            | 229   | 10.79 | 0.96  | 9.03  | 14.19 |
| Population*                                   | 229   | 14.02 | 0.80  | 12.85 | 17.36 |
| Territorial fragmentation*                   | 229   | 1.09  | 1.13  | −1.39 | 3.94  |
| Total land area*                              | 229   | 7.94  | 1.19  | 5.12  | 11.33 |
| Public transport policy (Mitigation)          | 229   | 0.61  | 0.49  | 0     | 1     |
| Legislative regulatory powers                 | 229   | 0.23  | 0.42  | 0     | 1     |
| Likelihood of enforcement                     | 229   | 0.19  | 0.39  | 0     | 1     |
| Metropolitan structure                        | 229   | 0.66  | 0.47  | 0     | 1     |
| **Level 3 (Country level)**                   |       |       |       |       |       |
| Independent variables                         |       |       |       |       |       |
| Country GDP*                                  | 16    | 1.38  | 0.44  | 0.15  | 1.96  |
| Modal split                                   | 16    | 24.12 | 19.35 | 3.57  | 79.16 |
| Propensity to travel                          | 16    | 13.9  | 1.25  | 10.8  | 15.57 |
| Transport energy intensity*                   | 16    | 0.03  | 0.11  | 0.02  | 0.05  |
| Environmental policy stringency              | 16    | 1.86  | 0.71  | 0.81  | 3.38  |
| Regional authority index                      | 16    | 23.06 | 9.05  | 3.8   | 36    |
| **Total number of observations**              | 687   |       |       |       |       |
| **Total metropolitan areas observed**         | 229   |       |       |       |       |
| **Total countries observed**                  | 16    |       |       |       |       |

*Represents a logarithm of the respective variable.
5. Estimation method

The expected outcome of CO₂ emissions in the transport sector, following Timilsina and Shrestha (2009), is specified as:

\[
\text{CO}_2\text{transportemission} = f\left(\text{cooperation, economicfactors, socio - culturalfactors, technologicalfactors, geographicalfactors, mitigationpolicy, enforcement, yearofobservation}\right)
\] (1)

In line with equation (1), we examine the extent to which metropolitan CO₂ transport emissions are determined by country characteristics, metropolitan characteristics and time using a random intercept, a random slope, and a growth curve estimation model.

Starting with a random intercept model, and following Rabe-Hesketh and Skrondal (2008) at level 1, the outcome “\(Y_{tij}\)”, (CO₂ transport emissions) for period ‘\(t\)’ in metropolitan area ‘\(i\)’ and country ‘\(j\)’ (Country) is represented as:

\[
Y_{tij} = \pi_{0ij} + \pi_{1ij} \times (a_{tij}) + e_{tij}
\] (2)

The \(\pi_{0ij}\) is the intercept and the \(\pi_{1ij}\) is the level-1 coefficient, with the corresponding \(a_{tij}\) being the level-1 predictor (‘year’ in this case). The \(e_{tij}\) is the level-1 random effect, with the assumption that \(e_{tij} \sim N(0, \sigma^2)\).

At level 2, in addition to yearly variation, the level-1 intercept (\(\pi_{0ij}\)) and residual \(e_{tij}\) are further broken down to include an explanation with metropolitan-level factors. These include effects of cooperation, metropolitan GDP, population, territorial fragmentation, total land area, mitigation policy, legislative regulatory powers, a likelihood of enforcement, and metropolitan structure. The relationship is expressed as:

\[
\pi_{0ij} = \beta_{0j} + \sum_{q=1}^{Q} \beta_{01} \times (X_{qij}) + r_{0ij}
\] (3)

The \(\beta_{0j}\) is the intercept; \(\beta_{01}\) is the level-2 coefficients; the \(X_{qij}\) is the level-2 predictors; and the \(r_{0ij}\) is the level-2 random effect.

At level 3, the level-2 new intercept (\(\beta_{0j}\)) and residual (\(r_{0ij}\)) are treated as outcomes to be predicted. This accounts for country-level factors that, aside from the metropolitan factors, can further influence and forecast the outcome of CO₂ transport emissions, and it is expressed as:

\[
\beta_{0j} = \gamma_{00} + \sum_{z=1}^{Z} \gamma_{01} \times (V_{zj}) + u_{0j}
\] (4)

The \(\gamma_{00}\) becomes the final intercept; the \(\gamma_{01}\) is the level-3 coefficients; the \(V_{zj}\) being level-3 predictors (country GDP, modal split propensity to travel, environmental policy stringency and regional authority index, transport factors,

etc.)
energy intensity), while $u_{0ij}$ is the level-3 random effect. Put together, the outcome ($Y_{tij}$) of CO$_2$ transport emissions at year ‘$t$’ in metropolitan area ‘$i$’ and country ‘$j$’ can be predicted as a mixed-effect random intercept model of the form:

$$Y_{tij} = \gamma_{00} + \pi_{tij}(a_{tij}) + \sum_{q=1}^{Q} \beta_{0q} \times (X_{qij}) + \sum_{z=1}^{Z} \gamma_{zq} \times (V_{zj}) + u_{0j} + r_{0ij} + e_{tij}$$  

(5)

The random intercept model assumes that the effect that cooperation has on CO$_2$ transport emissions is of the same slope for different metropolitan areas and across countries, just as the overall regression line. However, different metropolitan areas reduce their CO$_2$ transport emissions at different speed and scale. To capture this variation, we use a random slope model estimation:

$$Y_{tij} = \gamma_{00} + \pi_{tij}(a_{tij}) + \sum_{q=1}^{Q} \beta_{0q} \times (X_{qij}) + \sum_{z=1}^{Z} \gamma_{zq} \times (V_{zj}) + u_{0j} \times (a_{tij}) + r_{0ij} \times (a_{tij}) + u_{0j} + r_{0ij} + e_{tij}$$

(6)

In the random slope model, as indicated in equation (6), the total variance at level 3 ($u_{0j}$) is further broken down to include a function of the explanatory variable at level 1, $a_{tij}$. The same logic is applied to the total variance at level 2 ($r_{0ij}$) which now includes a function of the explanatory variables at level 1 as $r_{0ij} \times (a_{tij})$. The level-1 variance remains the same as it was in the previous model ($e_{tij}$).

Lastly, we estimate how governance measures at both the metropolitan and country levels determine CO$_2$ transport emission over time using a growth curve model estimation, which accounts for a variable specific rate of change and a cluster-specific random slope in predicting CO$_2$ transport emission. A random slope mixed-effect equation (7), which predicts a rate of change for the governance measures, is further specified as:

$$Y_{tij} = \gamma_{00} + \pi_{tij}(a_{tij}) + \sum_{q=1}^{Q} \beta_{0q} \times (X_{qij} \times a_{tij}) + \sum_{z=1}^{Z} \gamma_{zq} \times (V_{zj} \times a_{tij}) + u_{0j} \times (a_{tij})$$

$$+ r_{0ij}(a_{tij}) + u_{0j} + r_{0ij} + e_{tij}$$

(7)

What changes from the previous equation (6) is the interaction of the level-1 variable (year) with both the level-2 and level-3 predictors of governance measures. The $a_{tij}$ is the level-1 predictor, the $X_{qij}$ are level-2 predictors with $V_{zj}$ being level-3 predictors. $u_{0j}$ ($a_{tij}$) and $u_{0j}$ form the total level-3 random effect, $r_{0ij}(a_{tij})$ and $r_{0ij}$ are the total random effect for level-2 with $e_{tij}$ being the random effect for level-1.
The suitability of using a mixed model is tested by using a measure of intraclass correlation (see Hox 2010), which allows estimating the proportion of variance explained by clustering at the country and metropolitan levels. The formula for the interclass correlation is given by:

$$
\sigma_{\text{country}} = \frac{U_{0j}}{U_{0j} + r_{0j} + e_{ij}} \text{ and } \sigma_{\text{metro}} = \frac{U_{0j} + r_{0j}}{U_{0j} + r_{0j} + e_{ij}}
$$

where $\sigma_{\text{country}}$ is the country effect and $\sigma_{\text{metro}}$ is the metropolitan area effect considering its nestedness in the referred country. The $U_{0j}$, $r_{0ij}$, and $e_{ij}$ are the level-3, level-2, and level-1 residuals, respectively.

6. Results and discussion

In this paper, excluding a null model (Model 0), we estimate four model assumptions to test the impact of cooperation on CO₂ transport emissions. This includes the limited random intercept model (without country-level variables (Model 1), a complete random intercept model (Model 2), a random slope model (Model 3), and a growth curve model (Model 4).

The choice of the three-level mixed-effects linear model was based on the expectation that county characteristics would influence a metropolitan area’s CO₂ transport emissions. To test the model’s suitability, we assess intraclass correlation (Table 2) by first estimating a null model. The results indicate that the total residual that explains CO₂ transport emissions is made of a country-level variance at 1.50, a metropolitan level variance at 1.61, and a year of observation variance at 1.42 (Table 3). Correlating these variances, the intraclass correlation indicates that 41% of the variation in CO₂ transport emissions can be attributed to the influence of country-specific factors of a metropolitan area and 99% to the metropolitan area itself if respective country effects are not discounted from the metropolitan area effects. This suggests that the country has a significant contextual influence on CO₂ transport emissions in metropolitan areas. The result justifies the need for the hierarchical mixed-effects model specification, which fits better than a single level regression since it establishes effects across and within countries, taking into account implicit assumptions of linearity, homogeneity, and normality of residuals (Gelman 2006; see Appendix C for post-estimation tests).

| Table 2. Intraclass correlation matrix (ICC). |
|-----------------|-----------------|-----------------|
| Level           | ICC (null model)| ICC (model 1)   |
| Country         | 0.409           | 0.603           |
| MetroArea | Country         | 0.999           | 0.999           |
### Table 3. Results.

| Variables                              | (Model 0) Null model | (Model 1) Without country level variables | (Model 2) Random intercept (all levels) | (Model 3) Random slope (all levels) | (Model 4) Growth curve (all levels) |
|----------------------------------------|----------------------|-----------------------------------------|----------------------------------------|-------------------------------------|-------------------------------------|
| **CO₂ transport emissions**            |                      |                                         |                                         |                                     |                                     |
| **Level 1 (Year of observation)**      |                      |                                         |                                         |                                     |                                     |
| Year                                   | −0.08*** (0.02)       | 0.05 (0.05)                             | 0.09* (0.05)                            | −0.15 (0.12)                        |                                     |
| **Level 2 (Metropolitan level)**       |                      |                                         |                                         |                                     |                                     |
| Cooperation                           | −1.84*** (0.64)       | −1.69*** (0.53)                         | −0.97*** (0.37)                        | −1.48*** (0.57)                     |                                     |
| Metropolitan GDP (ln)                  | −0.05 (0.18)          | 0.67*** (0.24)                          | 0.10 (0.27)                            | −0.01 (0.22)                        |                                     |
| Population (ln)                        | 2.26*** (0.55)        | 2.00*** (0.54)                          | 2.04*** (0.74)                         | 2.14*** (0.79)                      |                                     |
| Territorial fragmentation (ln)         | 1.62*** (0.54)        | 1.31*** (0.43)                          | 1.00*** (0.33)                         | 1.10** (0.48)                       |                                     |
| Total land area (ln)                   | 1.47** (0.64)         | 1.16** (0.51)                           | 0.53* (0.28)                           | 0.52* (0.28)                        |                                     |
| Public transport policy (Mitigation)   | 2.36** (0.95)         | 2.08** (0.84)                           | 1.24* (0.71)                           | 2.52*** (0.97)                      |                                     |
| Legislative powers                     | 3.49 (3.00)           | 3.35 (2.92)                             | 3.29 (2.88)                            | 2.80 (3.28)                         |                                     |
| Likelihood of enforcement              | −2.60 (4.07)          | −2.69 (3.94)                            | −3.51 (3.78)                           | −1.68 (4.49)                        |                                     |
| Metropolitan structure                 | 0.87** (0.39)         | 0.70* (0.39)                            | 0.62* (0.32)                           | 0.95** (0.38)                       |                                     |
| **Level 3 (Country level)**            |                      |                                         |                                         |                                     |                                     |
| Country GDP (ln)                       | −0.58*** (0.14)       | −0.50** (0.21)                          | −0.11 (0.10)                           |                                     |                                     |
| Modal split                            | −0.00 (0.00)          | 0.01* (0.00)                            | 0.01 (0.00)                            |                                     |                                     |
| Propensity to travel                   | 0.14*** (0.04)        | −0.26*** (0.03)                         | −0.07* (0.04)                          |                                     |                                     |
| Transport energy intensity (ln)        | 0.81 (0.99)           | 1.27 (1.00)                             | 0.46 (1.07)                            |                                     |                                     |
| Environmental policy stringency (ln)   | −0.02 (0.04)          | −0.04 (0.04)                            | −0.16*** (0.05)                        |                                     |                                     |
| Regional Authority Index               | 0.05*** (0.02)        | −0.05 (0.05)                            | −0.00 (0.03)                           |                                     |                                     |
| **Governance Measures Overtime**       |                      |                                         |                                         |                                     |                                     |
| Cooperation*Year                       |                      |                                         |                                         |                                     |                                     |
| Territorial fragmentation (ln)*Year    | −0.01 (0.01)          | −0.08** (0.04)                          | −0.01** (0.00)                         |                                     |                                     |
| Public transport policy*Year           |                      |                                         |                                         |                                     |                                     |
| RAI*Year                               | 0.03* (0.02)          | −0.12** (0.06)                          | 0.13*** (0.04)                         |                                     |                                     |
| Legislative powers*Year                |                      |                                         |                                         |                                     |                                     |
| Likelihood of enforcement*Year         | −0.01 (0.01)          | −0.08** (0.04)                          | −0.01** (0.00)                         |                                     |                                     |
| Environmental policy stringency*Year   |                      |                                         |                                         |                                     |                                     |

*(Continued)*
### Table 3. (Continued).

| Variables                        | (Model 0) | (Model 1) | (Model 2) | (Model 3) | (Model 4) |
|----------------------------------|-----------|-----------|-----------|-----------|-----------|
|                                  | Null      | Without   | Random     | Random     | Growth    |
|                                  | model     | country   | intercept  | slope      | curve     |
|                                  |           | level     | (all levels) | (all levels) | (all levels) |
| Metropolitan structure*Year     |           |           |           |           |           |
| Intercept                        | 6.25***   | −39.37****| −22.80*   | −9.73     | −0.02     |
|                                 | (5.30)    | (11.52)   | (11.92)   | (9.96)    | (0.02)    |
|                                 |           |           |           |           |           |
| Random Effects                   |           |           |           |           |           |
| Lev 1 var(residual)              | 1.42***   | −1.52***  | −1.55***  | −1.79***  | −1.79***  |
|                                 | (4.77)    | (0.23)    | (0.22)    | (0.20)    | (0.21)    |
| Lev 2 var(cons)                  | 1.61***   | 1.30***   | 1.25***   | 1.33***   | 1.33***   |
|                                 | (7.66)    | (0.14)    | (0.15)    | (0.21)    | (0.21)    |
| Lev 3 var(cons)                  | −1.50***  | 1.52***   | 1.48***   | 1.35***   | 1.45***   |
|                                 | (−6.58)   | (0.20)    | (0.22)    | (0.20)    | (0.22)    |
| Lev 3 var(Year)                  |           |           |           |           |           |
|                                 | −1.83***  | −2.21***  | −0.43     | −2.32***  | −8.17***  |
|                                 | (0.25)    | (0.48)    | (0.31)    | (0.36)    | (3.67)    |
| Lev 3 var(Year-cons)             |           |           |           |           |           |
| Lev 2 var(Year)                  | −2.32***  | −2.33***  | −0.96     | −8.17***  |
|                                 | (0.36)    | (0.08)    | (0.75)    | (3.67)    |
| Lev 2 var(Year-cons)             | −10.10    | −10.10    | −16       | −16       |
|                                 | (31.01)   | (31.01)   | (16)      | (16)      |
| No. of Observations             | 687       | 687       | 687       | 687       | 687       |
| Country                         | 16        | 16        | 16        | 16        |
| Metropolitan Area               | 229       | 229       | 229       | 229       |

**Model Comparison**

| Log Likelihood                  | −799.97   | −726.03   | −696.65   | −622.98   | −614.88   |
|                                 | (31.01)   | (31.01)   | (31.01)   | (31.01)   | (31.01)   |
| BIC                             | 1626.07   | 1543.51   | 1532.95   | 1402.73   | 1432.27   |
|                                 | (1626.07) | (1543.51) | (1532.95) | (1402.73) | (1432.27) |
| AIC                             | 1607.94   | 1480.05   | 1433.30   | 1293.96   |
|                                 | (1607.94) | (1480.05) | (1433.30) | (1293.96) |

*p < 0.10, ** p < 0.05, *** p < 0.01. Robust Standard errors in parenthesis.
Table 3 presents the results of the four model estimations. Model 1 indicates the outcome of CO₂ transport emissions when predictors at the country level are excluded. The effect of cooperation on CO₂ transport emissions in the model (1.84% reduction) tends to be higher when compared to Model 2 (1.69% reduction), which includes the extent to which country-level predictors explain CO₂ transport emissions at the metropolitan level. Model 2 assumes that in the presence of cooperation, metropolitan areas will be equally able to reduce CO₂ transport emissions (by 1.69%). However, some metropolitan areas can be more effective in reducing CO₂ transport emissions than others. Model 3 captures this nuance and estimates a random slope in which the positive effect of cooperation on CO₂ transport emissions is comparatively lower at 0.97%. Model 3 demonstrates a better log-likelihood and model quality measures (BIC and AIC) which indicates its enhanced explanatory power vis-à-vis Models 1 and 2 (see Fabozzi et al. 2014). Lastly, Model 4 builds on Model 3 and accounts for the effectiveness of governance measures on CO₂ transport emissions over time. Compared to Models 2 and 3, we find a higher positive effect (1.48% reduction) of cooperation on CO₂ transport emissions as appreciable levels of stability and certainty in governance measures are achieved.

In all four models, excluding the null model, we use robust standard errors instead of asymptotic standard errors because they prove more reliable in multi-level regressions where the structure of variation is unknown (see Maas and Hox 2004).

Table 4 presents the summary of key findings from the results in Table 3.

As the findings presented demonstrate, inter-municipal cooperation on transportation issues in metropolitan areas reduces CO₂ transport emissions. Environmental policies matter, but their impact depends on enforcement at the metropolitan and national scales, which is facilitated through cooperation. This finding corroborates an increasing policy trend in instituting low emission zones (LEZ) and limited traffic zones through inter-municipal

| Variables                           | (Model 2) Random intercept (all levels) | (Model 3) Random slope (all levels) | (Model 4) Growth curve (all levels) |
|-------------------------------------|----------------------------------------|-------------------------------------|-------------------------------------|
| **Metropolitan level**              |                                        |                                     |                                     |
| Cooperation                        | −1.69*** (0.53)                        | −0.97*** (0.37)−1.48*** (0.57)      | 0.03* (0.02)                       |
| Cooperation*Year                   |                                        |                                     |                                     |
| Metropolitan GDP (ln)              | 0.67*** (0.24)                         | 0.10 (0.27)−0.01 (0.22)             |                                     |
| Territorial fragmentation (ln)     | 1.31*** (0.43)                         | 1.00*** (0.33)1.10** (0.48)         |                                     |
| Metropolitan structure             | 0.70* (0.39)                          | 0.62* (0.32)0.95** (0.38)           |                                     |
| Public transport policy (Mitigation)| 2.08** (0.84)                         | 1.24* (0.71)2.52*** (0.97)          |                                     |
| **Country level**                  |                                        |                                     |                                     |
| Country GDP (ln)                   | −0.58*** (0.14)                        | −0.50** (0.21)−0.11 (0.10)          |                                     |
| Environmental policy stringency (ln)| −0.02 (0.04)                          | −0.04 (0.04)−0.16*** (0.05)         |                                     |

*(ln)* represents a logarithm of the respective variable
cooperation in metropolitan areas for better environmental outcomes. Examples include the implementation of the Antwerp LEZ in 2017, Paris LEZ in 2015, Milano Area C in 2012, the Stockholm charging scheme in 2007, and the London congestion charge scheme in 2003, among others (see CLARS n. d.). The results of this study also indicate that CO₂ transport emissions reduction driven by cooperation improves at an estimated 0.03% annual rate of change in the longer run. This is consistent with the argument that institutions representing the formal and informal rules that organise social, political and economic relations tend to become more effective over time (North 1994; Przeworski 2004).

Further, we find that CO₂ transport emissions increase despite the mere presence of environmental mitigation policies. This is consistent with empirical observations. For example, while the Paris Agreement has 196 Parties adopting to limit global warming to less than 2 degrees Celsius, emissions have continued to rise globally by 1.4% per year on average since 2010 (UNEP 2020). Environmental policy effectiveness lies in the ability of the cooperating parties to ensure widespread policy implementation and enforcement (Hoel 1991; LaBelle 2012). In short, environmental mitigation policies require formal or informal enforcement mechanisms to become effective, which can be realised through cooperation.

We expected enforcement at the country level to have a larger effect than at the metropolitan level. The results indicate that CO₂ transport emissions reduce with enforcement at both the country and metropolitan levels in all models. However, with reference to Model 4, this is only statistically significant at the country level. The result highlights the persistence and relevance of vertical policy coordination between the national and metropolitan levels. With stringent environmental laws at the country level, metropolitan areas are more likely to reduce their CO₂ transport emissions. Thus, metropolitan areas located in environmentally conscious countries such as Sweden are better positioned to draw economies of scale effects from the implementation of environmental mitigation measures than metropolitan areas pursuing independent efforts in the absence of national environmental policies, which is the case for New York and Washington in the USA unilaterally adopting the Paris Agreement.

The expectation that better economic conditions at both the metropolitan and country levels could have both positive and negative effects on CO₂ transport emissions is confirmed in this study. While in general richer economies lead the fight against climate change, some of them at the same time double as its worst culprits (UNEP 2020). We find that a higher GDP at the country level reduces CO₂ transport emissions (0.58% in Model 2 and 0.50% in Model 3). However, higher GDP at the metropolitan level increases CO₂ transport emissions (0.67% in Model 2). While national funding can dictate climate-related interventions and standards, metropolitan wealth is more
flexible in taking on such obligations. As metropolitan areas are mainly production centres (UN-Habitat 2016), investments in environmentally-friendly interventions may be more easily sacrificed at the metropolitan level for economic gains.

Lastly, we find inconclusive evidence regarding the effectiveness of consolidated vis-a-vis fragmented metropolitan structures. On the one hand, metropolitan areas with consolidated structures record a positive correlation with CO$_2$ transport emissions. On the other hand, using the level of territorial fragmentation, more fragmented metropolitan areas record higher CO$_2$ transport emissions. The literature increasingly advocates fragmented metropolitan structures that favour voluntary cooperation, as compared to consolidated structures that address collective action problem through coercion (see Feiock 2013). However, our findings do not support this preference. While fragmented governance structures face a coordination challenge, consolidated structures run a high risk of freeriding, so both may yield inefficient outcomes. Thus, voluntary cooperation is neither better nor worse than coercion when environmental outcomes are at stake. This finding corroborates Visser (2002)’s assertion that governance structures have a mixed record, and thus effectiveness in urban problem solving depends on how the implementation of mitigation policies is managed (Andresson 2015).

What matters most for better environmental outcomes is neither mitigation policies nor metropolitan structure but inter-municipal cooperation. Cooperation at any level (local, metropolitan, national or international) facilitates policy coherence and ensures widespread enforcement of environmental mitigation policies for efficient outcomes.

7. Conclusion

This paper shows that cooperation in metropolitan areas makes a positive difference in delivering environmental outcomes. Metropolitan areas have emerged as a salient scale for public policy interventions to tackle global environmental concerns. The literature argues that inter-municipal cooperation in metropolitan areas is needed for better economic and environmental outcomes (Blair and Janousek 2013; Hawkins and Andrew 2011; UN-Habitat 2016; Visser 2002). Empirical evidence shows that inter-municipal cooperation saves costs, but does it also lead to better environmental outcomes? With a lack of cross-country empirical evidence, this study tests the relationship between cooperation and environmental outcomes to answer this question. We used ‘working together on transportation’ as a measure of cooperation and ‘CO$_2$ transport emissions’ for environmental outcomes to estimate the impact of cooperation on CO$_2$ transport emissions. With a novel dataset covering 229 metropolitan areas in 16 OECD countries, we employed a three-level mixed-effect model that accounts for contextual factors at both the metropolitan-level and country-level to
estimate and conclude that cooperation yields better environmental outcomes. We accounted for factors such as the year of observation, economic status, socio-cultural, geographical, technological and governance measures such as mitigation policies, enforcement, and metropolitan structure.

The study results are consistent with the normative prediction that cooperation leads to better environmental outcomes (Ahrend, Gamper, and Schumann 2014; Andersson 2013; Andresson 2015). Local governments that worked together on transportation issues in a metropolitan area showed a reduction in CO₂ transport emissions. This reduction further improves as the effects of institutions become evident over time. The results also indicated that mitigation policies alone do not have a positive impact on environmental outcomes. Rather, the possibility of widespread enforcement of policies, best at a higher government level, positively impacts CO₂ transport emissions. We tested if better economic conditions have a positive or negative effect on CO₂ transport emissions. The findings demonstrate that a higher GDP at the country level reduces CO₂ transport emissions, but a higher GDP at the metropolitan level conversely increases them. Finally, in contrast to the growing literature favouring voluntary cooperation in fragmented metropolitan areas over consolidated governance structures, we find that both led to higher CO₂ transport emissions. We conclude that inter-municipal cooperation presents a critical factor for ensuring better environmental outcomes in metropolitan areas, as it facilitates policy coherence and widespread enforcement irrespective of the type of metropolitan governance structure.

This study and the presented findings are not without limitations. First, due to data availability, the scope of the study is limited to the OECD countries. Additional research is needed to assess the impact of inter-municipal cooperation in metropolitan areas located in developing countries. Finally, a follow-up study will be necessary to capture the intensity of cooperation and longevity of the observed cooperation effects.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).

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