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Do Transnational Municipal Networks Accelerate the Net-Zero Transition? A Mixed-Methods Analysis of the C40 Cities Initiative and the Challenge of Urban Climate Change Mitigation

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ABSTRACT

Transnational municipal networks (TMNs) such as C40 or ICLEI have been posited to foster city-to-city learning in accelerating climate change mitigation and, thereby, facilitating the transition to net-zero greenhouse gas emissions. However, the existing literature on the role of climate networks has hardly examined the relationship between membership and climate change mitigation outcomes and impact, without which it is premature to be optimistic about TMNs role in the net-zero transition. In this article, we address this gap through a mixed methods analysis in the case of the C40 cities initiative. We combine a staggered difference-in-differences regression to shed light on the relationship between membership in the C40 initiative and carbon dioxide (CO_2) emissions during 2002–18 in over 700 OECD cities with a qualitative cross-case analysis of Bogotá, Colombia and Copenhagen, Denmark to unpack how and when the C40 initiative influences climate action at the city level. Results show that there is no statistically significant relationship between C40 membership and CO_2 emissions, indicating that cities in the C40 initiative may not have reduced CO_2 emissions more than other OECD cities, after controlling for socioeconomic characteristics, weather, country characteristics, city fixed effects, time fixed effects, and city-specific annual time trends. Furthermore, the complementary qualitative analysis showed the C40 network's direct intervention is limited to increasing or maintaining the ambition of cities; the network was found to have limited influence on city-level policy planning and implementation. There is a need to further study and address local policy implementation for realizing net-zero in relation to TMN membership.

1 | Introduction

The governance of climate change has become increasingly polycentric, involving multiple, overlapping, and autonomous centers of authority operating at different levels (Bulkeley 2005). Within this emerging architecture, cities are not only gaining greater legitimacy in global climate governance but are also challenging traditional political hierarchies through new horizontal and vertical linkages (Fraundorfer 2017; Niederhafner 2013; Toly 2008). They have also become strategic sites for transnational environmental governance, concentrating knowledge, infrastructure, and institutions critical for climate action (Bouteligier 2012). Building on these dynamics, transnational municipal networks (TMNs) have emerged as vehicles for addressing mitigation challenges by enabling cities to collaborate across jurisdictions (Busch 2015; Kern and Bulkeley 2009). These networks are often posited as means of accelerating the net-zero transition, enabling local experimentation (Bulkeley and Castán Broto 2013), fostering learning (Lee and van de Meene 2012), addressing complexity in spatial planning (Finka and Kluvánková 2015), promoting policy adoption (Emelianoff 2014), and diffusing climate policy innovations (Abel 2021; Hakelberg 2014).

Despite these expectations, the effectiveness of TMNs in reducing carbon dioxide (CO_2) or greenhouse gas (GHG) emissions—and, thereby, contributing substantively to the net-zero transition—remains an open empirical question. TMNs have been associated with important intermediate outcomes: they can help shape local climate agendas (de Macedo and Jacobi 2019) and promote the adoption of climate change mitigation policies by increasing technical assistance, capacity building, and international visibility (Lee and Koski 2014). However, these outputs do not necessarily translate into substantive mitigation outcome, and the effectiveness of TMNs in delivering impact in terms of real emissions reductions should not be assumed (Green 2015; Pattberg 2014). Yet, empirical evidence of GHG emissions reductions attributable to TMN participation remains limited (de Macedo and Jacobi 2019). Moreover, establishing a clear link between network agency and tangible climate change mitigation outcomes is challenged by slow impact and limited monitoring (Bansard et al. 2017; Trencher et al. 2016). This lack of clarity prevents an accurate appraisal of TMNs' effectiveness in polycentric systems, and blurs the line between symbolic action and dedicated efforts to achieve genuine decarbonization. Moreover, it hampers the ability to provide informed decision-making regarding resource allocation for the net-zero transition.

So far, only a few studies have sought to assess the influence of TMN membership on climate change mitigation. Qualitative case-based research reflects a mixed picture. Although Karhinen et al. (2021) find that Finnish municipalities participating in the Hinku network experienced lower GHG emissions, their findings are context-specific and difficult to generalize. In contrast, Valente de Macedo et al. (2016) show that while transnational engagement helped catalyze climate legislation in São Paulo, it had limited influence on implementation. Moving to quantitative studies, Khan and Sovacool (2016), who analyzed 25 cities reporting to the Carbon Climate Registry, found no significant difference in outcomes of GHG emissions between cities that reported climate commitments and those that did not. Hsu, Tan, et al. (2020), examining the EU Covenant of Mayors, concluded that approximately 60% of participating cities were on track to meet their 2020 GHG emission reduction targets. However, both studies focused primarily on cities in the Global North and relied on self-reported data. Collectively, these studies indicate that TMNs may indeed foster urban decarbonization. Nevertheless, critical gaps persist—most notably, reliance on self-reported emissions data, narrow geographical scope, and the lack of systematic evaluation of broader mitigation outcomes. As a result, it remains unclear whether—and under what conditions—TMN membership is associated with measurable climate change mitigation impact.

This study addresses this gap by examining whether TMN membership of cities is associated with climate change mitigation. More particularly, we pose the research question: "To what extent and in which way(s) do TMNs influence urban climate change mitigation?" Our analysis focuses on the case of the C40 Cities Climate Leadership Group, one of the most institutionally developed and prominent TMNs. The C40 initiative distinguishes itself through selective membership, structured reporting requirements, and explicit alignment with the goals of the Paris Agreement. Yet, there is currently only one large-n empirical study that addressed the influence of C40 on climate change mitigation; although this only focused on its influence on investment in solar photovoltaic energy (Steffen et al. 2019). Based on this, little can be said about contribution to climate change mitigation in a broader sense, let alone impact. To examine climate change mitigation outcome or impact more directly, we adopt a mixed-methods research design, combining econometric analysis of city-level climate change mitigation impact in terms of CO_2 emissions reduction with a complementary qualitative multicase analysis of local climate policymaking and implementation.

2 | C40 as a Transmunicipal Network

A TMN can be defined as a transnational institution that facilitates inter-city cooperation on (climate) governance (Busch et al. 2018; Kern and Bulkeley 2009). Its transnational scope distinguishes a TMN from other municipal (climate) networks, such as national or regional networks (Zapata Arango et al. 2024). The key characteristics of TMNs include (Busch and Anderberg 2015; Kern and Bulkeley 2009): (i) they are composed of more than two cities; (ii) participation is voluntary; (iii) they are self-governed; (iv) the members implement the goals and decisions of the network; and (v) they possess a degree of institutionalization and formalization. As a form of "soft governance" (Bouteligier 2012), a TMN is typically coordinated by a network-administrative organization, with moderate centralized governing power (Provan and Kenis 2008). Yet, while some TMNs are inclusive and open to diverse municipalities, others are considered more elite and accessible to only a few cities that meet certain criteria (Haupt and Coppola 2019).

The literature identifies five key mechanisms through which TMNs are posited to influence local climate action. First, TMNs promote knowledge diffusion and/or policy learning through peer-to-peer exchange (Haupt et al. 2020; Lee and van de Meene 2012). Second, they provide capacity-building and technical assistance to cities that may otherwise lack the institutional resources (Lee and Koski 2014; Sancino et al. 2022). Third, TMNs help place climate change mitigation on the local policy agenda (de Macedo and Jacobi 2019). Fourth, they promote norm diffusion through benchmarking and reporting (Gordon 2016). And finally, TMNs exercise soft conditionality through network influence, peer pressure, and recognition (Gordon 2016).

Nevertheless, several critiques have emerged. Scholars highlight that TMNs may inadvertently reinforce global inequities (Bouteligier 2012, 2013), as membership often skews toward wealthier cities in Europe and North America (Bansard et al. 2017) and knowledge often flows from the Global North to the South (Haupt et al. 2020; Mocca 2018). Others caution that participation may not necessarily translate into substantive climate action, potentially contributing to symbolic action or even "greenwashing" (Davidson and Gleeson 2015; Green 2015). Empirical evidence on climate change mitigation outcomes remains mixed: while some studies report positive effects (Hsu, Tan, et al. 2020; Karhinen et al. 2021), others find no significant impact (Khan and Sovacool 2016; Valente de Macedo et al. 2016). Therefore, a nuanced understanding of TMN influence must attend not only to ambition-raising and agenda-setting, but also to the complex and context-dependent pathways through which influence is (or is not) translated into substantive climate change mitigation (Frantzeskaki 2019).

Against this backdrop, the C40 Cities Climate Leadership Group offers a particularly revealing case to examine the opportunities and limitations of TMNs in advancing urban climate change mitigation. Founded in 2005 as a parallel initiative to the G8 Summit on Climate Change, C40 has evolved into one of the most prominent and institutionally developed TMNs focused on urban climate governance (Aust 2015). Initially established as a knowledge-sharing platform among megacities, C40 has since expanded its remit and membership, and now represents nearly 100 cities globally, covering nearly 600 million people and about 25% of the global economy (C40 Cities 2025). Its transformation has been shaped by a "twin diplomacy/planning approach" (Acuto 2013), in which cities engage both horizontally, with each other, and vertically, with international organizations, national governments, and the private sector.

Unlike more loosely coordinated TMNs, C40 adopts a relatively selective membership process and imposes specific requirements. Cities are expected to develop a climate action plan (CAP) aligned with the Paris Agreement's objectives, commit to a science-based emissions reduction target, and report progress through a standardized disclosure platform (Sancino et al. 2022). Through its climate action planning framework, C40 aids the development of this plan (C40 Cities 2020). Further, the network supports cities in addressing common challenges to ambitious climate action: (i) improving vertical and horizontal coordination; (ii) strengthening institutional capacity; (iii) developing a compelling case for climate action; (iv) understanding and engaging urban stakeholders; (v) collaborating with the private sector; and (vi) mobilizing finance for climate action (C40 Cities 2015). Together, these characteristics make C40 a particularly favorable—or "likely"—case for assessing whether TMN participation translates into measurable climate change mitigation.

Yet, questions remain regarding C40's effectiveness in translating climate ambition into tangible GHG or CO_2 emissions reduction. On the one hand, studies suggest that C40 has succeeded in placing climate change on the policy agenda (de Macedo and Jacobi 2019), facilitating knowledge sharing and policy learning (Lee and van de Meene 2012), promoting boundary spanning leadership (Sancino et al. 2022), and influencing global governance (Aust 2015). On the other hand, evidence of its direct impact on climate change mitigation remains limited (de Macedo and Jacobi 2019). Scholars have argued that the network is structurally constrained and ultimately reliant on (national) government support (Davidson et al. 2019; Giest and Howlett 2013). Further complicating the picture, Wiedmann et al. (2021) find that C40 cities may systematically underreport emissions, raising concerns regarding the accuracy of self-reported metrics. Accordingly, there is a pressing need to systematically assess whether—and under what conditions—C40 membership translates into demonstrable climate change mitigation impact.

3 | Research Design

We employ an explanatory sequential mixed methods design (Creswell and Creswell 2017) to examine whether and how membership in the C40 Cities Climate Leadership Group contributes to urban climate change mitigation. The research design reflects a dual ambition: to identify whether membership in the C40 network is associated with reductions in CO_2 emissions and to unpack the mechanisms through which such influence materializes. While the quantitative component analyzes the association of C40 membership with CO_2 emissions for a large panel of OECD cities, the qualitative component involves a cross-case comparison of two C40 cities to investigate urban policy processes in more depth.

3.1 | Quantitative Analysis

We construct an original panel dataset covering 795 cities in OECD countries between 2002 and 2018, of which 43 are members of the C40 network and 40 had joined the network during the timeframe of our analysis.

The main outcome variable is the total territorial CO_2 emissions (measured in metric tons), aggregated at the level of functional urban areas. We additionally use per capita emissions as an alternative outcome to test the robustness of our findings. The primary explanatory variable is a binary treatment indicator, coded as 1 beginning in the year a city joins the C40, and 0 otherwise, as membership is permanent during our study period. To account for other characteristics that influence CO_2 emissions and C40 membership, we control for variables that capture differences in socioeconomic conditions, weather, and country characteristics. These include city-level gross domestic product, population, population density, cooling degree days (CDD), and heating degree days (HDD). We further include national-level government effectiveness and the degree of political, administrative, and fiscal decentralization in the country as proxies for policy capacity and autonomy.

As noted earlier, a key challenge with measuring and assessing climate change mitigation at the city level is the paucity of data on greenhouse gas emissions (Hsu, Tan, et al. 2020; Kennedy et al. 2012). In this paper, we overcome this limitation by using spatially gridded fossil fuel-based CO_2 emissions estimates from the Open-source Data Inventory for Anthropogenic CO_2 (ODIAC) (Oda et al. 2018). While ODIAC does not measure emissions from bottom-up inventories, it has been shown to correlate strongly with self-reported data, for example, from the Covenant of Mayors (Hsu, Chakraborty, et al. 2020; Hsu et al. 2022). Additionally, we check whether CO_2 emissions calculated using ODIAC for this study and those as per a global dataset of CO_2 emissions taken from the CDP and other sources for 343 cities (Nangini et al. 2019) have a strong, statistically significant correlation.

Information on whether a city is a C40 member—and, if so, since when—is collected from the C40 website (C40 Cities 2025). However, as this does not have information on whether a city is a member as either a megacity, innovator city, or observer city, we are unable to control for the type of membership. The data on population, population density, GDP, CDD, and HDD is collected from OECD.stat (OECD 2025). As this data source does not contain any information on GDP at the city level, we use GDP at the level of the functional urban area as a proxy for city-level GDP. Meanwhile, the data on Government Effectiveness (GE) is collected from the World Governance Indicators dataset of the World Bank (Kaufmann et al. 2010), and the data on decentralization is collected from the Regional Authority Index (RAI) (Hooghe et al. 2016).

Our estimation strategy proceeds in four steps. First, we estimate a series of generalized difference-in-differences (DiD) models using two-way fixed effects (TWFE). These models include city and year fixed effects, as well as city-specific linear time trends to account for unobserved heterogeneity and differential baseline trajectories. Covariates are added sequentially to examine the robustness of the treatment effect to alternative specifications. We also estimate variants with per capita emissions as the outcome variable and include 1-, 2-, and 3-year lags of the independent variable to capture potential delays in CO_2 emissions reductions following network membership.

Second, recognizing the limitations of TWFE models under staggered treatment adoption and heterogeneous effects, we turn to the estimator developed by Brantly Callaway and Sant'Anna (2021a). Employing not-yet-treated cities as the control group, this method allows for group-time average treatment effects to vary across joining cohorts and event time. This estimator is particularly appropriate for our setting, where cities join C40 in different years and "effects" are likely to evolve over time. The approach accommodates both dynamic and group-level heterogeneity, and provides formal tests for the parallel trends assumption.

Third, to assess the sensitivity of our findings to sample composition, we estimate the Callaway and Sant'Anna model on a matched subsample. Nearest-neighbor matching is performed on pretreatment covariates observed in 2004, including population, GDP, HDD, CDD, GE, and RAI. We select 2004 as the matching baseline to ensure all cities are included prior to the formation of the C40 initiative. Cities in the treated and control groups are matched without replacement (i.e., one non-member city is chosen per member city). To ensure the reliability of our estimates, we repeat the analysis after excluding cities that are only observed for a short period of time. This helps to confirm that our findings are not driven by cities with limited information before or after joining the C40 network.

Finally, to align cities on a common event-time scale and avoid implicit reweighting from staggered adoption, we implement the imputation-based event study of Borusyak et al. (2024). This approach first fits an outcome model on untreated observations (never-treated and not-yet-treated cities), with city and year fixed effects and the same covariates as in our main TWFE model. Predicted values from this model provide counterfactual emissions absent C40 membership; event-time effects $ATT(\tau)$ are defined as observed minus imputed outcomes, aligned by years since joining. For inference, we use a like-for-like window that retains only cohorts observed at every event year from $\tau = -3$ to $\tau = +5$ (i.e., 3 years pretreatment to 5 years posttreatment). We report the equal-τ average over the posttreatment years ($\tau = 1 \ldots 5$).

The analyses were performed using the R programming language version 4.4.2 (R Core Team 2024) with the following packages: "ClimActor" (Hsu, Yeo, et al. 2020), "did" (Callaway and Sant'Anna 2021b), "didimputation" (Butts 2021), "fixest" (Berge 2018), "MatchIt" (Ho et al. 2011), "modelsummary" (Arel-Bundock 2022), and "tidyr" (Wickham et al. 2024). Standard errors were clustered by city and year in the generalized DiD models, were robust in the Callaway and Sant'Anna estimation, and were clustered by city for the Borusyak, Jaravel, and Spiess imputation. Dynamic treatment effects are visualized using event-study plots to facilitate interpretation.

Parts of the R code were drafted and refactored using ChatGPT (OpenAI; GPT 5 Thinking). All code was reviewed, tested, and—where needed—rewritten by the authors. The tool was not used to create, alter, or manipulate original research data. The authors take full responsibility for the integrity and accuracy of the analysis.

3.2 | Qualitative Analysis

Establishing a clear link between city-level climate actions and CO_2 emissions reductions remains a challenging task. To complement the quantitative analysis and probe the mechanisms of influence more deeply, we adopt a multicase study approach to explore how C40 membership may shape local climate policymaking and implementation. This qualitative component is designed to examine the contextual, institutional, and political conditions under which transnational engagement contributes to—or fails to contribute to—urban climate change mitigation.

To guide the qualitative analysis, we synthesize two frameworks. First, the framework by Hale et al. (2021) outlines a process through which cities move from setting ambitious targets to achieving measurable impact. This framework is particularly useful for tracing C40's potential influence along a value chain of climate action, from agenda-setting and target formation to implementation and outcomes. It allows us to identify *whether*, *where*, and *how* C40 interventions influence municipal processes and lead to substantive mitigation outcomes and impact. Second, to account for the structural and governance dimension, we draw on Hoppe et al. (2016). Their framework emphasizes the dynamics of multilevel governance, recognizing that municipalities may lack jurisdictional authority over certain emission-intensive sectors or may face capacity constraints that inhibit implementation. The framework enables a more contextualized understanding of how internal (e.g., administrative) and external (e.g., political, regulatory) factors influence local climate governance and the role of transnational networks within these dynamics.

The case selection was informed by the results of the quantitative analysis and follows a "deviant case" logic (Gerring 2006), selecting cases that reflect variation in mitigation performance while also differing in institutional and geographical context. We examine two cities: Bogotá (Colombia) and Copenhagen (Denmark). These cases represent variation not only in their observed emissions trends, but also in geography, governance, institutional context, population, and size. In addition, while Bogotá is a member under the "Megacities" category,

TABLE 1 | Descriptive statistics for OECD cities analyzed.

	Mean	SD	Minimum	Maximum
Emissions ($MtCO_2$)	5.39	13.20	0.02	194.74
Emissions per capita (tCO_2 per capita)	7.59	7.78	0.44	73.74
C40 membership (1: yes)	0.04	0.19	0.00	1.00
Population ('000 persons)	777.62	2077.41	8.08	34364.26
Population density (Persons per km^2)	1342.44	1246.28	7.00	10974.00
Gross domestic product ('000 USD)	69.07	146.82	0.96	1800.72
Cooling degree days (degree C)	199.35	348.19	0.00	2619.00
Heating degree days (degree C)	2047.25	1105.96	0.00	5756.00
Government effectiveness (number)	1.25	0.58	−0.30	2.35
Regional authority index (number)	23.01	9.45	0.00	37.72
N				12,779

Copenhagen belongs to the "Innovator Cities" cohort. Finally, the cases represent the Global North and the Global South, providing insight into whether and how TMN dynamics differ between the two.

Data for the case studies is collected through a combination of primary and secondary sources. For each municipality, at least two semi-structured interviews were conducted with C40 representatives, municipal officials, or researchers with expertise on the local climate policy context. Additional data was obtained from climate action strategies, official planning documents, and third-party reports. The material was analyzed using qualitative content analysis, and individual case reports were developed to support cross-case comparison. All coding and analysis were conducted using Atlas.ti (ATLAS.ti Scientific Software Development GmbH 2023).

4 | Results

4.1 | Quantitative Analysis

We begin by examining descriptive patterns in the dataset, which includes over 12,000 city-year observations across 700 OECD cities between 2002 and 2018 (Table 1). Average annual territorial CO_2 emissions per city are 5.39 million metric tons (SD: 13.30), with substantial variation across cases—from Rolleston, New Zealand (0.02 Mt) to Tokyo, Japan (194.74 Mt). Per capita emissions average 7.59 tons. On average, cities in the C40 network differ substantially from non-members: they are larger, more populous, and wealthier. C40 cities emit significantly more CO_2 on average (32.72 Mt. vs. 3.81 Mt) but less per capita (6.24 vs. 7.66 tCO_2), reflecting their larger population but greater emissions efficiency relative to scale. Yet, variability within groups is substantial (Figure 1).

Turning to our baseline models, we estimate generalized DiD regressions with two-way fixed effects and city-specific time trends. Across specifications, we find no statistically significant association between C40 membership and either total or per capita emissions (Table 2). In our most comprehensive model, the coefficient for C40 membership is 0.57 (95% CI: −0.83, 1.98). This null result holds across lagged models that include 1-, 2-, or 3-year treatment delays. These findings suggest that C40 membership is not associated with measurable reductions in emissions at the city level, either immediately or with delay.

In contrast, several control variables behave as expected. For example, GDP is positively associated with total emissions, while population density is negatively associated with per capita emissions, indicating the role of compact urban form in reducing carbon intensity. Similarly, higher heating degree days (HDD) are also linked to higher emissions, reflecting increased energy demand in colder climates. Interestingly, government effectiveness is positively associated with emissions, which may reflect better monitoring and reporting capacities. Regional authority, on the other hand, has a negative coefficient, possibly indicating that greater local autonomy in climate policymaking is associated with higher emissions reduction.

Recognizing the limitations of standard DiD under staggered treatment adoption, we next implement the Callaway and Sant'Anna estimator, which allows for treatment effect heterogeneity by cohort and event time. The overall average treatment effect on the treated (ATT) remains statistically insignificant (ATT = 1.06, 95% CI: −1.30, 3.33), suggesting no generalizable emissions effect from C40 membership. However, the disaggregated results reveal that only the 2005 cohort has sufficient posttreatment data for estimation. For this group, even the treatment-year ATT is imprecise and non-significant.

More notably, as shown in Figure 2, the dynamic specification reveals a statistically significant decline in emissions in the year before treatment (ATT = −2.15, 95% CI: −3.25, −0.78), with a formal pretrends test rejecting the parallel trends assumption ($p = 0.003$). This suggests that cities may begin reducing emissions in anticipation of C40 membership, or that selection into the network is correlated with preexisting decarbonization trajectories. The absence of robust posttreatment effects—coupled

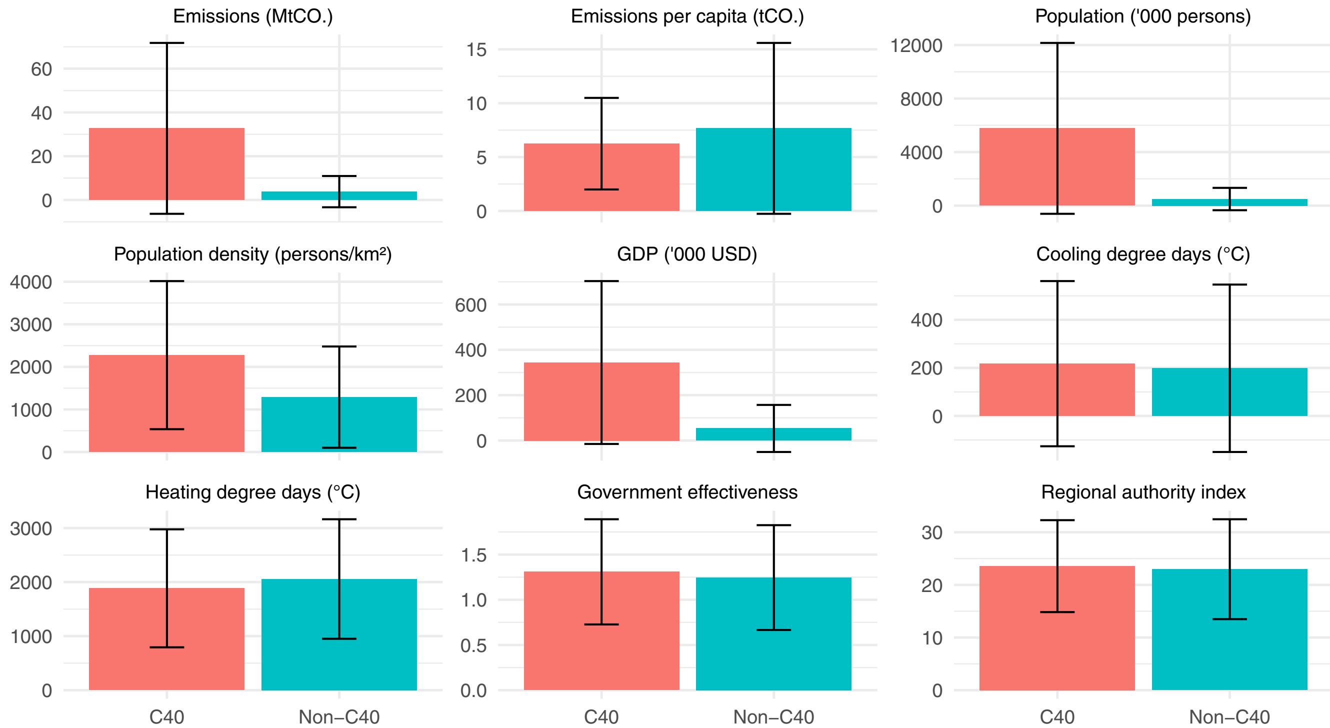

FIGURE 1 | Means and standard deviations by C40 membership.

TABLE 2 | Regression of fossil fuel-based carbon dioxide emissions on C40 membership.

	(1)	(2)	(3)	(4)	(5)
C40 membership	0.618	0.591	0.592	0.574	0.573
	[−0.839, 2.075]	[−0.789, 1.972]	[−0.789, 1.973]	[−0.831, 1.979]	[−0.833, 1.978]
Population density	—	−0.000	0.000	0.000	0.000
		[−0.001, 0.001]	[−0.001, 0.001]	[−0.001, 0.001]	[−0.001, 0.001]
Population	—	−0.001	−0.001	−0.002	−0.002
		[−0.008, 0.005]	[−0.008, 0.005]	[−0.008, 0.003]	[−0.008, 0.003]
Cooling degree days	—	—	0.001	0.001^{+}	0.001
			[−0.000, 0.001]	[−0.000, 0.001]	[−0.000, 0.001]
Heating degree days	—	—	0.000	0.000*	0.000*
			[−0.000, 0.000]	[0.000, 0.000]	[0.000, 0.000]
Gross domestic product	—	—	—	0.036***	0.036***
				[0.018, 0.054]	[0.018, 0.054]
Government effectiveness	—	—	—	—	0.307**
					[0.099, 0.515]
Regional authority index	—	—	—	—	−0.042*
					[−0.077, −0.006]
N	12,779	12,779	12,779	12,779	12,779
Adjusted R^2	0.996	0.996	0.997	0.997	0.997

$^{+}p<0.1$.
$^{*}p<0.05$.
$^{**}p<0.01$.
$^{***}p<0.001$.

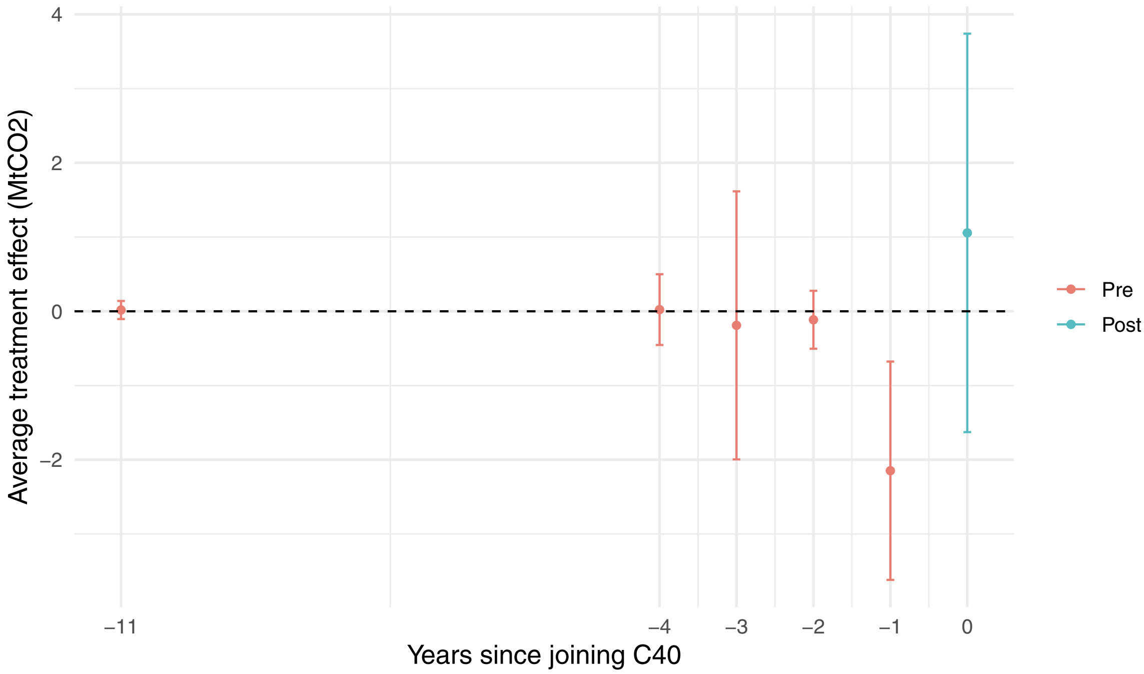

FIGURE 2 | Dynamic average treatment effects of C40 membership on fossil fuel-based CO_2 emissions. Effects are plotted by event time, with 95% confidence intervals. Negative event times indicate premembership period.

with the significant pretreatment dip—raises concerns about causal inference in this setting.

To assess the robustness of these findings, we re-estimate the Callaway and Sant'Anna model using a matched sample of treated and control cities. Matching on pretreatment covariates from 2004 ensures that comparison groups are more closely similar in terms of population, GDP, climate, and institutional context. The results remain consistent: the average ATT is statistically insignificant, and the pretreatment decline for the 2005 cohort persists. We further exclude cities with limited temporal coverage to rule out bias from short panels. These sensitivity checks reaffirm the main pattern: no discernible posttreatment effect and a significant emissions dip just before C40 membership.

Using our prespecified like-for-like window with 3 years pretreatment and 5 years posttreatment, the Borusyak, Jaravel, and Spiess imputation yields an equal-τ average ATT of −0.17 with a 95% CI [−1.19, 0.86], indicating no statistically significant postmembership reduction. Varying the posttreatment duration from 2 to 8 years also yields statistically insignificant estimates for ATT, confirming the robustness of this finding. Further, pretrend diagnostics in this approach do not reject the parallel trends assumption (pooled pre-ATT $p=0.574$; linear pretrend $p=0.853$). Overall, the results of the Borusyak, Jaravel, and Spiess approach corroborate the TWFE and Callaway and Sant'Anna findings of no robust posttreatment effect of C40 membership on city-level CO_2 emissions.

Taken together, our quantitative analysis provides little evidence that C40 membership is associated with emissions reductions at the city level. While the network may still play an important role in shaping local climate agendas, its effects are not readily visible in aggregate emissions data postmembership. However, the reduction in emissions prior to joining C40 might indicate that the selection mechanism used by C40 may encourage cities to undertake climate change mitigation actions to obtain membership. Yet, we cannot establish whether these are anticipatory effects or selection bias. These findings underscore the need for caution in interpreting treatment effects in transnational governance settings, and motivate the need for complementary qualitative analysis to uncover how and under what conditions urban climate networks influence mitigation outcomes and impact.

4.2 | Qualitative Analysis

4.2.1 | The Case of Copenhagen

Copenhagen is the capital and most populous city of Denmark. It is situated on the eastern coast of Zealand, along the Øresund strait. At the time of writing, the Copenhagen municipality (Københavns Kommune) was led by Lord Mayor Lars Weiss, appointed in October 2020. The population of the core area is 580,184 inhabitants with a GDP of 111 billion USD (2015). Copenhagen holds a permanent C40 office, which was opened in 2017 by the previous Lord Mayor Frank Jensen, and which served as a center for "the network's global Business, Economy and Innovation programme" (C40 Cities 2017). Copenhagen is admitted under the Innovator City membership and belongs to three sub-networks in C40: transportation and urban planning; Food, waste and water; and adaptation and implementation. Besides the C40 Cities climate network, the city also participates in other TMCNs such as the Covenant of Mayors, the Compact of Mayors, and the Carbon Neutral Cities Alliance. The municipality has adopted three CAPs over the last two decades. The latest version states that Copenhagen should become the world's first carbon-neutral capital city by 2025 (City of Copenhagen 2012). Prior to the Paris Agreement in 2015, Copenhagen enjoyed a dedicated history of engagement in climate change and ambitious targets with significant reductions that took place from the 2005–2015 period, owing to its previous two CAPs. The key takeaway from the first evaluation was that Copenhagen was on its way to reach the 2025 targets, although additional measures were needed, owing to some national policies such as congestion zone and changes to energy taxes failing to materialize. On the contrary, progress at the national level on wind power and biomass exceeded expectations, and CO_2 reductions were achieved considerably faster than envisioned (City of Copenhagen 2012).

4.2.2 | The Case of Bogotá

The City of Bogotá, the capital district of Colombia, is one of the main megacities in Latin America with a population of 8.7 million inhabitants and one of the biggest economies in Colombia with a GDP of USD 188 billion. Located in the center of Colombia, Bogotá has an area of nearly 1600 km^2. The city is part of several city networks; it is a member of C40 with a megacity membership profile and has also participated in multiple subnetworks of C40. In addition, Bogotá is also part of the steering committee for C40. Besides Bogotá's socio-economic problems, climate change puts Colombia's capital at extreme climate threats that include flooding, wildfires, and mass movement (C40 Cities 2021). The reported CAP enlisted five goals revolving around: decreasing CO_2 emissions, saving and managing water, increasing capacity for adaptation, fostering collective action, and promoting transformative cultural change in society. The CAP reflects Bogotá's ambitions, although the prepared plan lacks rigor in terms of implementation, resources required, and monitoring progress. In the context of climate mitigation, the city of Bogotá aims to cut its CO_2 emissions by 56% by 2038, 62% by 2050, and the intended goal for 2025 is to stabilize its per capita emissions by 2 tons as the upper limit (City of Bogotá 2021). The plans align with the Paris Agreement, where Bogotá aims to become carbon neutral by 2050. The municipality wants to increase the use of energy-efficient technologies, implement PV solar energy in various sectors, enforce sustainable construction, and reduce the carbon footprint of existing buildings, which is a bit of an overlap with the adaptation plans. Furthermore, the aim is to have "zero waste" by implementing circularity in industrial processes, construction, and thermolysis of the solid waste generated.

4.2.3 | Comparison of Copenhagen and Bogotá

Table 3 presents an overview the two cases. Bogotá and Copenhagen present a large degree of variation in terms of culture, geography, history with climate change, climate risks and socio-political system. Interestingly, the influence of the C40 network membership is considered to be stronger in Bogotá. This is related to C40 particularly focusing more on cities in the Global South for two specific reasons: (i) cities in the Global North already have better capacities and resources to tackle climate change; and (ii) most of the finances are earmarked to supporting assistance towards the Global South. For both cities the study revealed that C40 membership strongly influenced cities increasing or maintaining climate change mitigation ambition. Second, C40's influence is limited to factors that indicate intra-municipal support, i.e., input, throughput and output clusters of climate action at the local level which is indicated by improved capacities, catalyzing climate action and policy learning from experimentation. Third, C40 is known for lobbying at international climate summits and encouraging mayors to take leadership roles in global climate change politics, hence indicating a casual influence on higher-level government. Both the Bogotá and Copenhagen cases were extensively showcased by C40 which contributed to city branding, resulting in an improved stance and global image. This was important in the case of Copenhagen to drive the reform in national legislation. However, the case studies did not provide much empirical evidence for C40 empowering the cities to implement climate change mitigation plans (i.e., with objectives adopted from C40), which were delayed and eventually faced substantial barriers. The main barriers identified in the cases pertained to alignment with national government interests, finance, shift in political power, and engagement of private sector and civil society actors. The inability of C40 membership to directly influence the intended climate actions contradicts any hypothesis of a direct positive relationship between C40 network membership and impact (i.e., leading to a significant decrease in CO_2 emissions).

5 | Discussion and Conclusion

Despite high expectations surrounding the potential of TMNs to drive urban climate action, this study finds no statistically significant relationship between C40 membership and reductions in either total or per capita CO_2 emissions. Rather than interpreting this as a simple failure of C40 or similar networks, the results point to more fundamental challenges in the political economy of transnational climate governance. TMNs may play an important role in setting ambitious agendas, fostering international visibility, and catalyzing intra-urban capacity building, but their ability to deliver measurable decarbonization outcomes and impact remains constrained by structural, institutional, and contextual barriers.

These findings contribute to an emerging strand of literature that urges a more critical and differentiated understanding of the functions of TMNs. Much early scholarship celebrated city networks as engines of climate innovation and experimentation, suggesting that cities, through horizontal collaboration, could bypass the inertia of national and international climate regimes. However, our results align more closely with recent assessments that caution against overestimating the causal influence of TMNs on climate outcomes and impact (Hickmann et al. 2017). In particular, they highlight that while TMNs may succeed in mobilizing symbolic commitments and raising local climate ambition, translating these ambitions into tangible emission reductions as achieved impact remains elusive. For example, Tosun and Leopold (2019) find that although TMNs commonly adopt ambitious goals—such as in urban water management—their actual influence on local policymaking is often limited, suggesting that network membership frequently serves symbolic and goal-setting purposes rather than impactful and transformative ones, which require sound implementation in complex settings.

The findings also call attention to three key mechanisms limiting the mitigation impact of TMNs. First, structural selection effects are evident: C40 membership is skewed toward wealthier,

TABLE 3 | A cross-case comparison of Copenhagen and Bogotá using criteria from Hale et al. (2021) and Hoppe et al. (2016).

	Copenhagen	**Bogotá**
C40 membership	Innovator city	Megacity
Urban city type	Large metropolitan area	Metropolitan area
Vulnerable to climate change	Medium	High
Ambition	++	++
Alignment with the COP21 goals ('Leadership standards)	Membership requirement	Membership requirement
Input	±	+
Presence of GHG inventory	Membership requirement	Membership requirement
Financial resources	Substantial budget of its own allocated, no financing required from C40	Limited capacity financed; partially from CFF and some from the national government
Human resources	Sufficient personnel available as well as a C40 office	Limited staff within the municipality, although C40 provides dedicated personnel support
Regulatory authority	High internal knowledge and expertise; C40 showcases it as 'best practice'	Some internal knowledge but limited experience; both direct and indirect support from C40
Throughput	±	+
Political will to act	Stable and sound	Very committed but with conflicting history
Commitment (by staff)	High commitment; being part of C40 improves motivation	Commitment varies; membership boosts motivation of the staff
Inter-departmental collaboration	Sufficiently established coordination prior to joining C40	Sufficiently established coordination; C40 engagement was crucial
Knowledge management	Strong knowledge base; C40 highlights best practices	Some, but mostly outsourced; C40 provides assistance with partners from various consultancies
Monitoring and evaluation	Present. Multi-year with feedback loop to policy	Absent
Output	–	–
Policy instruments	Comprehensive set of policy instruments	Limited set of policy instruments
Municipal governing type	Collaborating	Collaborating and Providing
Influence other tiers of government	+	+
Linkage between national and local level	Only rarely misalignment occurs	Improved over the years
Presence of intergovernmental support schemes	Both national and provincial schemes apply that support municipalities	Fluctuating but has increased from the base year 2010

(Continues)

TABLE 3 | (Continued)

	Copenhagen	Bogotá
Implementation	±	–
Implementation of projects	Half of the plans are in the implementation stage	No plans implemented; Half of the plans are still in the scoping phase
Size and intensity of mitigation projects	Comprehensive	Comprehensive but with limited actions
Outcome and impact	±	–
CO_2 emission reduction	Decreased level of CO_2 emissions; but relation with C40 membership not established.	Increased level of emissions; no direct relation with C40 membership.
Climate co-benefits	Green economy. Ecosystem preservation	Setting higher targets' improved air quality

institutionally capable cities, which already exhibit higher levels of ambition and capacity. This "pioneers of pioneers" effect (Kern and Bulkeley 2009) complicates efforts to attribute subsequent emission reductions to network membership itself, rather than preexisting trajectories. Second, the symbolic politics of TMNs matter: participation often conveys international recognition and reputational rewards without necessarily generating enforceable obligations for substantial action. Third, governance constraints persist: even committed cities remain embedded in multilevel political systems, where local authority, financial autonomy, and regulatory capacity are frequently limited. This tension between cities' climate aspirations and national constraints reflects broader struggles over the role of cities in global governance. As Aust (2015) argues, conflicts such as the standoff between U.S. cities and the federal government over climate policy are emblematic of a deeper shift in the international legal order, raising questions about how power is and will be distributed between states and an increasingly assertive league of cities and subnational actors.

The case studies of Bogotá and Copenhagen provide further empirical grounding for these dynamics. Both cities clearly benefited from C40 membership in terms of international visibility, climate agenda setting, and institutional learning. In Copenhagen, C40 affiliation reinforced already-strong municipal capacities and enhanced the city's global leadership profile. However, even here, achieving full carbon neutrality was hampered by dependencies on national-level policies beyond municipal control. In Bogotá, meanwhile, C40 membership provided crucial technical assistance, ambition-raising, and capacity building in a more resource-constrained setting, yet major barriers—such as financing gaps, intergovernmental coordination problems, and political turnover—severely limited implementation of local climate policy. These findings echo concerns that TMNs alone cannot compensate for systemic inequalities in urban governance capacities, particularly between cities in the Global North and Global South.

More broadly, the study challenges the assumption that transnational urban governance is inherently more effective than national or international processes. It underscores that achieving meaningful urban decarbonization depends less on network affiliation per se and more on the availability of supportive national or international policy frameworks such as the EU Horizon Program or Interreg, sustained political leadership, access to finance, human and institutional capacity for policy implementation, and enforcement. While TMNs such as C40 provide important arenas for norm diffusion, capacity building, and political signaling, they are insufficient substitutes for the hard, contested work that is needed for achieving structural transformative change and climate change mitigation impact.

These results also carry methodological implications. The use of independently observed emissions data (such as ODIAC) rather than self-reported inventories enhances the credibility of the findings and helps address prior concerns about selection and reporting biases in TMN evaluations (Wiedmann et al. 2021; Lee and Koski 2014). At the same time, the significant pretreatment reductions observed among C40 members highlight the difficulty of fully isolating causal effects and caution against overly simplistic evaluations of network performance.

Several limitations of this study should be acknowledged. First, while the quantitative analysis covers 795 cities across OECD countries, the sample remains skewed toward the Global North. As such, the findings may not generalize to cities in the Global South, where governance capacities, access to finance, and political dynamics differ significantly. Second, although we use spatially gridded CO_2 emissions data from ODIAC—which avoids biases associated with self-reported inventories—this dataset captures only fossil fuel-based CO_2 and omits other relevant GHGs (e.g., methane), consumption-based emissions, and co-benefits such as air quality. Third, our primary treatment variable—C40 membership—is modeled as a binary, time-invariant indicator, which does not capture heterogeneity in the depth, timing, or quality of engagement. Cities may vary in how actively they participate in C40 initiatives, while network requirements and support structures have evolved over time. Fourth, data limitations prevented the inclusion of potentially important covariates such as sectoral emissions profiles, industrial activity, or local policy stringency. Fifth, while the matched and fixed effects models improve insight into causal inference, the presence of anticipatory behavior and significant pretreatment effects suggest that selection bias remains a challenge. Finally, this study focuses exclusively on climate change mitigation. It does not address other important dimensions of climate governance, such as adaptation, resilience, vulnerability or any climate justice outcomes, which are also central to the missions of many TMNs.

Future research should shift focus from asking whether TMNs matter to probing under what conditions and through what mechanisms they exert influence. Comparative studies that incorporate governance capacity, financial autonomy, political leadership dynamics, and multilevel institutional arrangements will be crucial for understanding the uneven impacts of city networks. The relationship between local autonomy in climate policymaking and climate change mitigation also deserves further attention. Moreover, attention to the Global South remains imperative, not only because of increasing urbanization pressures but also because the effectiveness of TMNs as platforms for capacity-building and transformation may be most critically tested in resource-constrained contexts.

In sum, this study suggests that TMNs such as the C40 have significant but fundamentally limited roles in advancing urban climate mitigation. Their contributions lie primarily in catalyzing ambition, supporting local policy making, developing capacity, enabling learning, and building symbolic capital, rather than directly delivering emissions reduction. Realizing the full potential of urban climate governance will require moving beyond network participation to focus on strengthening the enabling conditions for sustained, equitable, and transformative decarbonization across diverse urban contexts.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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