Does What Gets Measured Get Done? An Evaluation of the Impact of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories on City Climate Action

Final Report

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List of acronyms

BAU	Business as usual
C40	C40 Cities Climate Leadership Group
CAP	Climate action plan
cCR	carbonn Climate Registry
CIFF	Children's Investment Fund Foundation
CIRIS	City Inventory Reporting and Information System
CO2e	Carbon dioxide equivalent
CURB	Climate Action for Urban Sustainability
DID	Difference-in-differences
GDP	Gross domestic product
GHG	Greenhouse gas
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
Gt	Gigaton (billion tons)
HDI	Human Development Index
IPCC	Intergovernmental Panel on Climate Change
IQR	Inter-quartile range
ITT	Intent-to-treat
M&P	C40's Measurement & Planning team
MOU	Memorandum of understanding
Mt	Megaton (million tons)
OECD	Organisation for Economic Co-operation and Development
TA	Technical assistance
TOT	Treatment-on-the-treated
UN	United Nations
UNDP	United Nations Development Programme
WRI	World Resources Institute

Executive summary

As the world more aggressively moves to address climate change, data is becoming increasingly important in guiding climate policy to be efficient and effective in reducing greenhouse gas (GHG) emissions. Cities are essential stakeholders in climate policy formulation and execution by virtue of being the primary source of global GHG emissions; cities currently account for approximately 70 percent of global energy-related CO_2 emissions (UN HABITAT 2011). An accurate inventory of all GHG emissions is central to forming an effective climate change mitigation strategy. Comprehensively documenting all emissions sources through a consistent and transparent methodology will make it possible to track cities' climate efforts over time and to make meaningful cross-city comparisons of GHG emissions. The 2014 launch of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), a city-level, emissions-reporting protocol, made those objectives easier to achieve by offering a standardized framework that could serve as the gold standard for all cities to adopt.

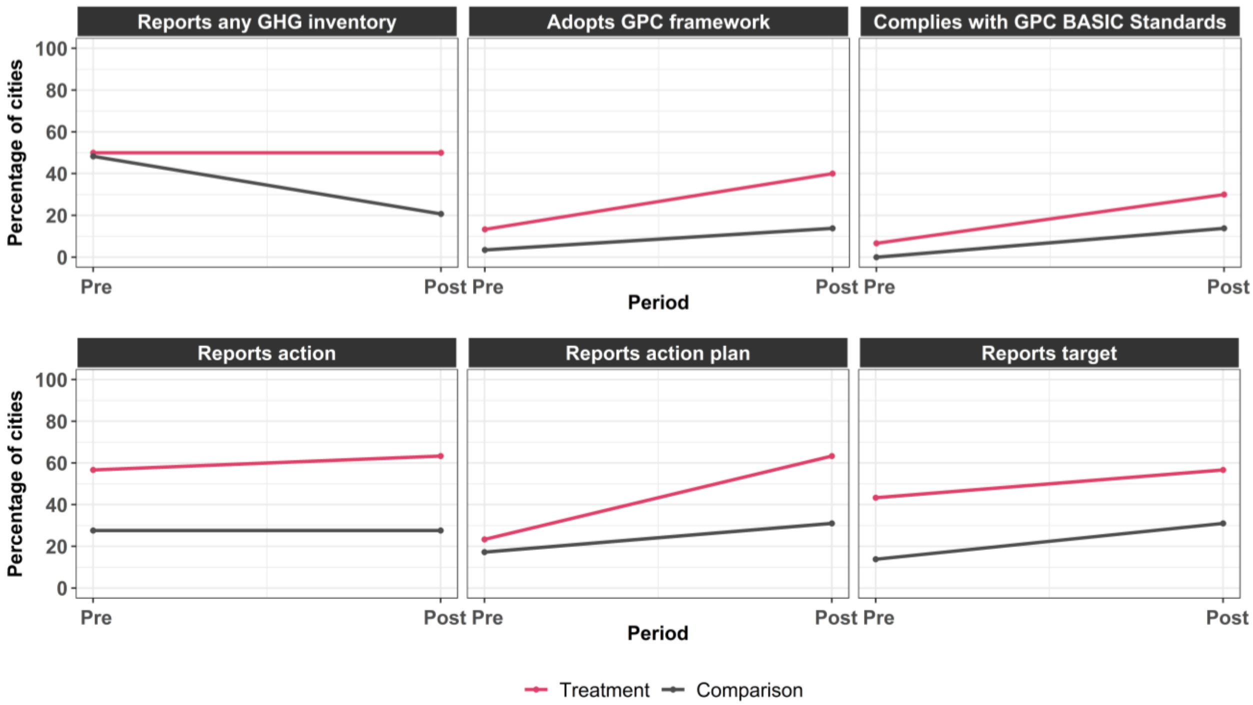
Not all cities have been actively engaged in measuring their emissions. Developing an accurate and comprehensive inventory requires trained staff with the skills to analyze emissions data streams from a range of sectors and organizations. Many cities lack staff with such specializations. Therefore, C40, a global network of megacities committed to preventing climate change, developed a technical assistance (TA) program to support cities in building a GPC-compliant inventory that could serve as the foundation on which to base climate actions and emission reduction targets. The Children's Investment Fund Foundation (CIFF) financed the expansion of the TA program to 30 C40 member cities in Africa, Asia, and Latin America to accelerate their climate action. CIFF commissioned Mathematica as the independent evaluator of C40's TA program; this report contains our final findings on the program's effectiveness.

Our evaluation of the CIFF-funded, C40-implemented TA program to support Global South cities develop GHG inventories finds:

- **Most cities that ever participated in TA complied with the program's immediate objectives of generating GHG inventories, and most inventories are based on the GPC framework.** In the period immediately following program completion (2016–2019), 50 percent of the 36 cities that were ever selected to participate in the TA program reported at least one GHG inventory. Eighty-three percent of these cities' inventories were based on the GPC framework, although cities did not necessarily report emissions for all the sectors and scopes encompassed by the framework. A high proportion of cities also reported climate action plans, or CAPs (58 percent), mitigation actions (64 percent), and emissions reduction targets (55 percent).
- **High turnover and resulting differences in the intensity of program participation affected ever-participating cites' capacity to achieve full compliance of program objectives.** Cities that began the program early and stayed in the program had the highest pair-wise completion rates over all outcomes, meaning that average participation levels are not representative of the outcomes of cities that complete the program as intended. If this observation holds, we expect that cities that joined the program late may improve their reporting levels as they move forward in their engagement with the program which is expected to conclude in December 2020.

- **Relative to a group of comparison cities, cities selected for C40's TA program performed better in the reporting of GHG inventories and CAPs when comparing performance in 2016–2019 following the start of TA ("post") to performance in 2011–2015 prior to the start of TA ("pre"), as shown in Figure ES.1.** Our analyses suggest that cities that participated in TA were 28 and 27 percentage points more likely to report a GHG inventory or a CAP, respectively. We interpret these outcomes as evidence of TA's capacity to increase GHG inventory reporting and that increased reporting, in turn, enables cities to take more effective climate action—which first begins with the identification and development of mitigation actions.
- **Relative to comparison cities, we find that TA had small, positive effects on the reporting of mitigation actions (7 percentage points).** This effect is not commensurate with the change we observe in cities' reporting of CAPs, possibly because their CAPs may be based on actions that cities are yet to implement. We expect that cities' reporting of mitigation actions may improve as they move towards finalizing and implementing their CAPs.
- **TA had a slightly negative effect on the reporting of emission reduction targets.** Cities selected for TA were 4 percentage points less likely than comparison cities to report an emissions reduction target. This result is driven by TA as well as by comparison cities increasing their rates of emission reduction target reporting over time, but comparison cities register a larger increase. We consider this outcome to be partly driven by the timing of the evaluation since program implementation delays resulted in several participant cities receiving TA later than anticipated. As the process of devising an emission reduction target is likely to be politically charged and time-consuming, it is possible that late entrants were simply unable to complete one within the evaluation timeframe. As with mitigation actions, we anticipate that emission reduction target reporting rates will further increase among TA recipients after their TA engagement concludes and cities have finalized their CAPs.
- **Cities that actually received TA reported consistently larger effects than cities invited to participate in the program**. Our group of TA cities includes cities that were selected for TA but did not receive it and comparison cities that received TA; 28 of the 36 cities selected to receive TA actually participated in the program. We account for these compositional changes by running separate analyses of program effects on the set of actual TA recipients and their comparison group counterparts. These analyses find larger positive effects among cities that actually received TA. For instance, we find that cities that participated in the program are 30 percentage points more likely than comparison cities to report a GHG inventory and 33 percentage points more likely to report completing a CAP.
- **Despite finding TA has positive effects for most key outcomes, we are unable to confirm that these positive effects were statistically significant for any outcome of interest.** We test the robustness of our effect estimates generated by our preferred model (presented above) by running a battery of sensitivity checks that employ different estimation procedures, sets of control variables, weighting approaches, and inclusion criteria. We estimate large confidence intervals overlapping a zero effect size accompany the point estimates in nearly all outcomes' regression results, partly due to the small sample size of cities receiving TA and their comparison cities. As a result of the large confidence intervals, we cannot statistically rule out the possibility that the program had no effect on the outcomes of interest. Nonetheless, since the analyses for most outcomes produced positive and often quite large point estimates, the results present suggestive evidence of TA having a beneficial effect on outcomes such as GHG inventory and mitigation action reporting.

Figure ES.1. Reporting of GHG inventories, mitigation actions, climate action plans, and emission reduction targets over time for cities receiving TA and comparison cities



Source: Authors' calculations using data from C40, cCR, CDP, Kummu et al. (2019), UN, and WRI.

Notes: All outcomes are binary variables and defined in Table A.2. The pre-period covers CDP's 2011 to 2015 reporting years, whereas the post-period spans 2016–2019. The figure displays percentages for treatment and comparison cities in the intent-to-treat sample.

- **We find no evidence that GPC adoption in itself led to more or better mitigation actions or emission reduction targets.** We compared cities that adopted the GPC framework in compiling their inventory to those that did not and find both groups exhibited similar reporting rates of mitigation actions and emission reduction targets. The most notable difference in reduction target outcomes between these two groups of cities was in the target type, with GPC adopters disproportionately choosing targets that were set relative to a business as usual (BAU) scenario.

Although we find that the TA program contributed to recipient cities reporting higher levels for the outcomes of interest, cities still have room for growth in their inventory completeness and the quality of mitigation actions and emission reduction targets. We offer recommendations to strengthen those outcomes, including conducting a post-TA learning assessment to identify participants' views on the most effective TA components and any remaining needs, having C40 work with cities to develop a timetable to make further improvements in inventory reporting, and encouraging cities that are engaging with emissions data and climate policy but who are yet to report those efforts to engage with data platforms (like CDP) to make their efforts observable to other cities and researchers.

I. Introduction

Key takeaways on GHG reporting

- In this section, we describe the motivation for the TA program, including the importance of data for city-level climate policy and of promoting the reporting of emissions data through a systematic, high-quality framework.
- GHG inventories that use a consistent, transparent methodology to comprehensively document a city's emissions sources are central to the formation of effective climate change mitigation strategy, as they provide data needed to prioritize climate efforts, track progress over time, and make meaningful cross-city comparisons of GHG emissions.
- The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), a GHG inventorying methodology launched in 2014, offers cities a standardized framework that is widely considered the gold standard for city-level emissions reporting.
- The GPC values relevance, completeness, transparency, consistency, and accuracy of reporting and uses a territory-based accounting method that calculates a city's total emissions as the sum of all relevant sources. The framework organizes reporting into three scopes and five sectors.
- An inventory's "quality" is a byproduct of many factors, including the accuracy, recency, and representativeness of all the activity and emissions factor data upon which it is based. The number of scopes and subsectors covered by an inventory, a city's confidence in the inventory, and the process of obtaining external verification of inventory contents are all considered indicators that provide insight into inventory quality.

As the world continues urbanizing, with cities forecast to house more than two-thirds of the global population by 2050 (UNDESA 2018), the importance of cities' efforts to address climate change will increase only further. Cities are currently estimated to be the source of 70 percent of global energy-related CO_2 emissions; as they continue to grow in population and economic size over coming decades, that figure is expected to rise (UN HABITAT 2011).[1] Even though climate policy has historically been the purview of countries, cities have demonstrated that many levers to support decarbonization are in their control and that their size makes them ideal experiments for testing innovative climate policies, assessing their results, and supporting one another through peer networks to encourage the adoption of those found to be most effective.

An accurate and timely GHG inventory is central to a city's climate policy efforts. A GHG inventory reports the sum total of all GHGs emitted across a city's emission sources, including those from buildings, transportation, industry, waste, and land use. GHG inventories reveal a city's key emission sources, which vary across cities, and can help prioritize where mitigation efforts should be directed (Hoornweg et al. 2011). When conducted regularly, inventories over time can support the monitoring of a city's mitigation progress and can aid policymakers in assessing whether they are on track with their emission reduction targets. If monitoring reveals that a city is off track, corrective measures can be identified by examining the latest inventory results.

[1] UN HABITAT (2011, pg. 52) cites a prior United Nations Environment Programme report that states a potentially lower urban share of global anthropogenic GHG emissions (40-70 percent) than the urban share of energy-related CO_2 emissions, because of emissions arising from deforestation and other land use change practices. Satterthwaite (2008) notes that the urban share of emissions depends on the allocation practices used in assigning non-city emissions that are generated in the production of goods and services consumed by urban dwellers.

In the absence of a universally adopted international standard for city-level inventorying, a GHG inventory's total estimated emissions reflect, in part, methodological choices and user discretion (Hoornweg et al. 2011). Macro-level decisions that need to be made include defining a city's boundary that geographically delineates which emissions fall under a city's responsibility, which GHGs to include and for which emitting sources data need to be collected.[2] Furthermore, inventory contents are based on numerous decisions that operate at more granular levels, such as how to collect survey data on transportation patterns, how to respond when factories do not report on-site emissions, and which choices related to emission factors are appropriate when only national grid data are available. In the absence of common accounting practices and methodological choices, cities have been free to pursue non-standardized methods in emissions calculations such that comparisons across cities, and even within cities, are less meaningful over time than if all inventories adhered to the same accounting practices (Dahal and Niemelä 2017).

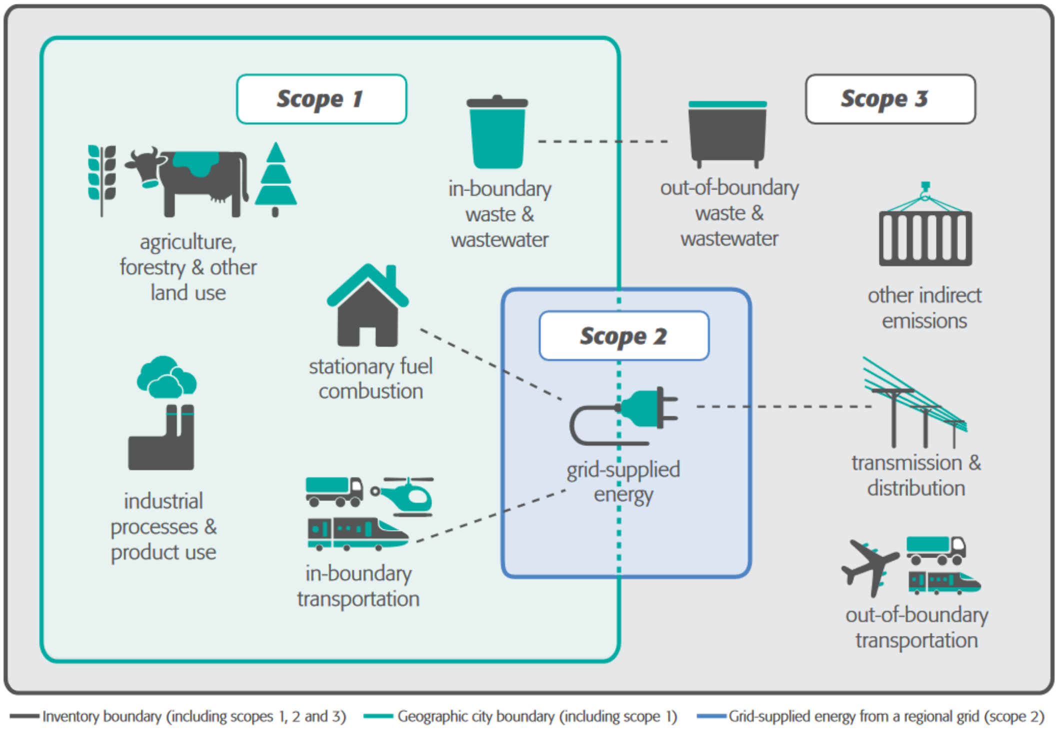
In 2014, C40, ICLEI, and the World Resources Institute (WRI) launched the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) to supplant existing inventorying methods and serve as the global standard methodology undergirding city GHG inventories.[3] The Greenhouse Gas Protocol, a consultative body tasked with developing GHG accounting standards, oversaw the GPC's development and review process by convening representatives from many of the organizations that had devised earlier city inventorying methodologies. The GPC framework prioritizes *relevance, completeness, transparency, consistency, and accuracy* (WRI et al. 2014a) as accounting principles to maximize the inventory's usefulness as a tool for comparison across cities and within a city over time.

The GPC uses a territory-based accounting method that calculates a city's total emissions as the sum of all relevant sources. In Figure I.1, we diagram how the GPC categorizes emissions, with each icon representing a sector (for example, transportation, waste) and organized by scope according to the location of the emissions. Each sector further encompasses several subsectors, with transportation, for example, disaggregated into on-road, railway, water-borne navigation, aviation, and off-road subsectors.

- *Scope 1* emissions are emitted inside the city's geographic boundaries;
- *Scope 2* emissions are produced from the generation of electricity, heat, steam, and/or cooling that is consumed within the city by buildings or grid-connected transportation (for example, light-rail transit, electric vehicles); and
- *Scope 3* emissions are emitted outside the city boundaries but are caused by economic activity occurring inside the city. For example, aviation emissions for flights departing from an airport that serves a city but that is located outside it will partially be accounted for by the city's scope 3 emissions as per explicit guidance.

[2] The Intergovernmental Panel on Climate Change (IPCC) tracks the following seven GHGs: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen triflouride.
[3] The final version of the GPC was released in December 2014, though the origins of the initiative date back to 2011 when C40 and ICLEI signed a memorandum of understanding to develop the protocol.

Figure I.1. GPC's emission sources by scope



Source: WRI et al. (2014a).

Compliance with the GPC framework is achieved by adopting the guiding accounting principles in the inventory development process and satisfying reporting requirements. BASIC inventories are those that include scope 1 and scope 2 emissions subtotals from stationary energy and transportation and the scope 1 and scope 3 emissions from waste (WRI et al. 2014a). The more demanding BASIC+ level requires all BASIC standards to be met and includes scope 1 emissions from industrial processes, agriculture, and land use as well as scope 3 emissions from stationary energy and transportation.[4] Even though the "quality" of an inventory is a byproduct of many factors, including the accuracy, recency, and representativeness of all the activity and emissions factor data upon which it is based, along with the definition and implementation of data quality assurance and quality control procedures, the number of scopes and subsectors covered by an inventory, a city's confidence in the inventory, and the process of obtaining external verification of inventory contents are all considered indicators of a higher quality inventory. In contrast, inventories that report the bare minimum and do not make transparent their modeling assumptions and data choices would be perceived as a lower quality inventory.

The GPC was established to resolve several analytic limitations that arose from the previous patchwork of city inventory methodologies, with the aim that it would grow in value with wide adoption. Most important, a common accounting approach would enable meaningful comparisons across cities (Gordon and Johnson 2018). Differences in a city's emissions over time could be more reliably interpreted as true differences rather than as artifacts from methodological choices such as boundary-setting or the composition of emissions sectors (Dahal and Niemelä 2017). If the GPC were universally adopted, then mitigation actions undertaken or proposed could be aggregated to calculate abatement totals without worry of double-counting across reporters (Hsu et al. 2019). In addition, even though protocol adoption does not innately resolve the data availability or data quality issues often faced by cities, the GPC's systematic nature helps spotlight data availability gaps and forces users to be transparent when they do not report emissions components or data sources.

Universal adoption of the GPC was not ensured at the time of its creation. To accelerate GPC adoption, C40, a global network of megacities committed to addressing climate change at the city level and one of the co-creators of the GPC, established a technical assistance (TA) program intended to build capacity and support cities as they compiled their first GPC inventory. The TA program aimed to help recipient cities overcome resource constraints that may have prevented them from both undertaking an inventory and instituting climate action-setting processes on their own. The Children's Investment Fund Foundation (CIFF), one of C40's Strategic Funders, provided financial support to extend the program to approximately 30 C40 member cities in the global south. The TA program complemented other C40 efforts to institutionalize the GPC as the standard required by other city-focused climate policy initiatives, such as the Compact of Mayors and later the Global Covenant of Mayors.

By partnering with C40, cities would gain access to expert knowledge and fast-track the process of not only developing an inventory but also of producing a higher quality inventory than if they undertook an inventory without C40's support. With credible emissions data in hand, cities could then pursue climate actions that were guided by actual data and that would provide a baseline against which subsequent climate action progress could be compared. The provision of TA would be temporary, but the program was expected to build sufficient local capacity in the cities' sustainability offices and in other relevant departments to sustain inventory revisions and reporting after the TA's termination.

[4] WRI et al. (2014a) provide a complete description of the sub-sectors which must be reported to meet the BASIC and BASIC+ levels.

This report is Mathematica's final evaluation of the CIFF-funded C40 TA program and builds on previous years' reports and memoranda on the TA program (Naeve et al. 2017; Thornton et al. 2017; D'Agostino et al. 2019; Thornton et al. 2019). *The evaluation's key objectives are to understand the effectiveness of TA delivery in supporting cities' efforts towards the goal of collecting GHG emissions data, reporting a GHG emissions inventory, and developing mitigation actions.* Of particular interest is an assessment of whether TA motivates cities to carry out GHG inventories and adopt the GPC framework at rates higher than would have occurred in the absence of the TA program. Our findings on the program's effects are based on a quantitative assessment of cities' reported GHG inventories, climate actions, and emission reduction targets. We use a matched comparison group design to construct a counterfactual of the extent of climate data and climate policy action that cities receiving TA would have been likely to pursue in the absence of the TA program. For outcomes with small sample sizes caused by a limited number of cities engaging in a particular type of climate data reporting, we perform cross tabulations rather than regressions to understand differences between comparable groups of cities that differ in whether they received TA. To the best of our knowledge, this is the first evaluation conducted of any program whose explicit objective is to assist cities in compiling an accurate GHG inventory that would serve as the foundation upon which robust climate actions would be developed.

The remainder of the report is organized as follows. In Section II, we provide an overview of the C40 technical assistance program aimed at supporting cities in developing GHG inventories that adopt the GPC framework. In Section III, we present our research design by describing the data sets used in our analyses, the guiding research questions and outcomes of interest, and our methodological approach, including a matched comparison group design and application of descriptive statistics. In Section IV, we describe our main empirical findings for the impacts of the TA program on the completion of GHG inventories and on the setting of climate actions and emission reduction targets. In Section V, we report the results from a descriptive comparison of cities that adopted the GPC framework in completing their GHG inventory versus those that did not, to determine if there are discernible differences across the groups in the quantity and quality of undertaken climate actions and emission reduction targets. We present our key conclusions and recommendations in Section VI.

II. Overview of C40’s GPC-compliant GHG inventory technical assistance program

Key takeaways on C40’s TA program

- This chapter describes the design, requirements, and primary activities of C40’s TA program. It also describes cities selected to the program and their trajectory through the program.
- C40's TA program sought to build capacity and support cities in the completion of a GHG inventory that adopted the GPC framework, with the expectation that a completed inventory would provide the foundation for cities to devise data-driven mitigation actions and emission reduction targets.
- The Children’s Investment Fund Foundation (CIFF), one of C40’s Strategic Funders, initially provided financial support to extend the program to approximately 30 C40 member cities located across the Global South.
- TA used city-specific implementation teams to (1) conduct a gap analysis used to identify information needed compile a GPC BASIC-compliant inventory, (2) provide ongoing assistance to support inventory, (3) review city inventories to ensure compliance with the GPC framework, (4) support a scenario planning workshop designed to help city identify emission reduction strategies.
- Cities selected for TA differed in their level of engagement with the program. Eight of the original 30 cities that were selected left the program or were removed for various reasons; six replacement cities not initially selected took their place; and 22 cities that were selected for participation from the start have either completed or are expected to complete the full program. The TA program was still ongoing at the close of the evaluation period, given the challenges caused by COVID-19, and was expected to conclude in December 2020.
- There was not a standardized timetable that applied to all TA recipients; the timing of TA support and its duration varied across recipient cities.

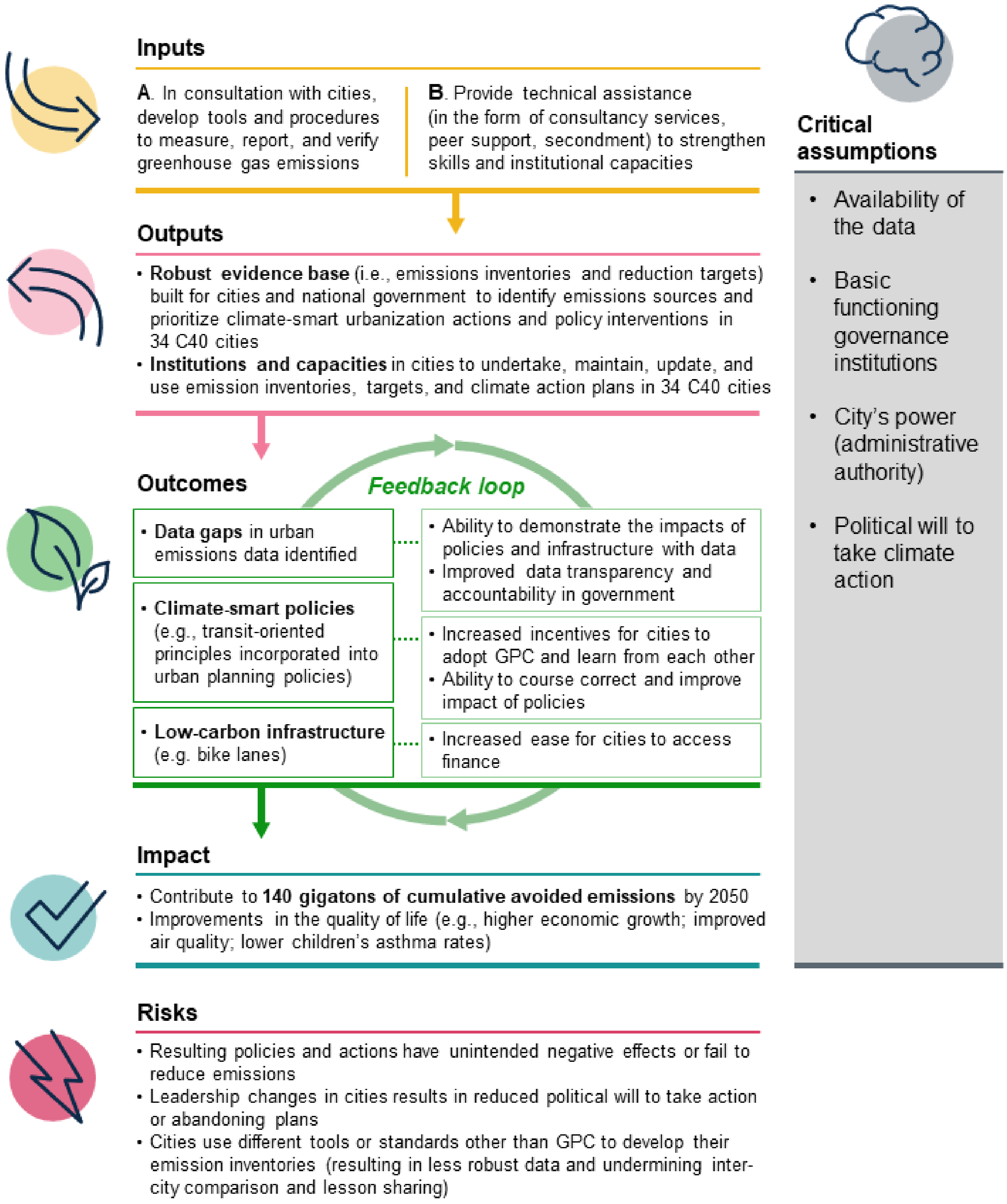
C40 developed a TA program to support the efforts of cities that both i) adopted the GPC framework and ii) committed to compile a GHG inventory. As part of its climate change portfolio, CIFF invested in the program, which was intended to provide TA services to 30 to 35 C40 member cities in Africa, Asia, and Latin America. These cities are experiencing rapid population and economic growth and, over the next several decades, will continue to invest in infrastructure in response to that growth. The TA program aimed to help guide cities onto a low-emissions development pathway, as indicated in the program’s theory of change (Figure II.1) and to avoid locking in long-term emissions growth from ignoring the climatic implications of those investment decisions (Ürge-Vorsatz et al. 2018). The targeted number of cities was later reduced to 28 as part of a C40-CIFF agreement to redirect funds to other C40 programs.

By focusing efforts on numerous cities simultaneously, the TA program intended to create a community of practice across cities, spurring other cities’ adoption of the GPC in response to the learning opportunities available from already adopting cities. Most recipient cities had limited experience in any GHG inventorying methods, and only one city (Lima, Peru) had experience with the GPC at the time the TA program was conceptualized. C40 provided direct assistance through a city-specific delivery team, described below. The TA process guided each city in completing its first GPC-compliant inventory, thereby building internal capacity to continue the work after the delivery of technical assistance and ensuring a commitment to updating the inventory regularly.

The completion of a GPC-compliant inventory was the most immediate objective of the TA program, but a completed inventory provided the foundation for cities to devise data-driven mitigation actions and emission reduction targets. The inventory creation process permits policymakers insight into a city's key emission sources and builds confidence in identifying which emitting sources should be prioritized by mitigation activities. Furthermore, by building confidence in the GPC as a stable methodology that aimed indefinitely to be the default protocol, policymakers would be assured that their emission reduction efforts could be reliably measured by routine inventory updates. Through those measurements, urban planners could be accountable for climate-focused investments and would have the tools to calculate the GHG reductions accruing from climate actions undertaken by the city.

The TA program's ultimate goal was to accelerate mitigation action in those cities directly receiving TA and, through peer learning and economies of scale, to contribute to C40's aim of delivering 140 gigatons (Gt) of CO_2-equivalent (CO_2e) reductions by 2050, as seen in the 'Impact' portion of the theory of change. Furthermore, the TA program sought to remedy the mismatch between major sources of future emissions growth and the current composition of cities engaging in climate action. As late as 2018, 91 percent of cities participating in key climate networks and reporting forums hailed from North America and Europe (UNEP 2018), even though the majority of emissions growth through 2050 is expected to come from countries outside the Organisation for Economic Co-operation and Development (OECD), an intergovernmental body primarily comprising rich countries.

Figure II.1. Theory of change behind the C40 technical assistance program



Source: Adapted from CIFF (2015).

A. Components of the technical assistance program

After C40 and CIFF agreed on which cities would be invited to receive TA, the then chair of C40 extended invitations to those cities' mayors to participate in the program. In exchange for receiving free TA, the cities that signed the TA program's memorandum of understanding (MOU) committed to several prerequisites to ensure the program's success. Chief among those requirements were for recipient cities to (1) designate a senior staff person to work with C40 and champion the TA's objectives in local government channels, (2) guarantee one full-time equivalent technical staff person who would be available for the work, (3) host and provide logistical support for two in-city workshops, and (4) participate in related opportunities for peer learning and exchange of best practices. The cities that signed the memorandum of understanding (MOU) and committed the aforementioned resources would then receive the TA delivery displayed in Figure II.2, with each city receiving a program tailored to its circumstances and any existing data and processes.

Figure II.2. Schematic illustrating the components of C40's technical assistance program

Source: Adapted from C40 (2016b).

C40 connected each city in the program to an implementation team composed of C40 staff and consultants tasked with carrying out TA provision. Implementation teams were led by or included staff from C40's Measurement and Planning (M&P) initiative, the C40 regional director for that city's region, a C40 secondee, the C40 city adviser, and/or a consultant with expertise in GHG inventory development who would serve as the "delivery partner."[5]

After assembling the implementation team, the first TA component consisted of a gap analysis to identify which gaps needed to be remedied in order to compile a GPC BASIC-compliant inventory. For cities without a GHG inventory at that time, the delivery partner reviewed all available data sources to determine how best to proceed with creating a GPC BASIC inventory. For cities with an existing inventory, the delivery partner assessed it against the requirements of a GPC BASIC inventory and documented all revisions required to bring the inventories into compliance. Typical revisions called for collecting and reporting additional data, improving data quality, and providing calculations, methods, and data sources used in emissions calculations.

The gap analysis findings shaped the focus of a locally hosted GPC workshop. During this two-day workshop, the delivery partner—with staff from M&P, C40 secondees, and/or city advisers—conducted an in-person training session to build city officials' capacity to create a GHG inventory. Workshop topics included the value of inventory development and emissions reporting, the contents of the GPC protocol, and best practices in data management and in use of the [City Inventory Reporting and Information System (CIRIS)](#) reporting tool, among others. Following the workshop, the implementation team provided ongoing assistance to support development of the inventory.

[5] Both Buenos Aires and Vancouver provided city officials who acted as secondees to support the TA program. C40 city advisers were awarded to a small number of cities through a call for applications, including two of the evaluation's intervention cities (Addis Ababa and Shenzhen). More information on C40's City Advisers program is available at https://www.c40.org/programmes/city_advisers.

Once a city completed its initial inventory, it submitted it to C40 for review. The M&P team reviewed inventories for compliance with GPC BASIC requirements and, if it found an inventory noncompliant, worked with the delivery partner to clarify and address remaining gaps until BASIC compliance was achieved.

After resolving all the outstanding data gaps and finalizing a compliant inventory, a city then hosted a scenario planning workshop during which the implementation team helped the recipient city identify emission reduction strategies. Strategies were to be aligned with the Paris Agreement's goal of containing average global temperature growth to 2.0°C above pre-industrial levels and preferably to less than 1.5°C. The work included supporting the development of a business-as-usual (BAU) emissions forecasts and reduction trajectories to 2050 through use of the Excel-based Climate Action for Urban Sustainability (CURB) tool (World Bank 2017). Scenario forecasting and simulations of potential mitigation pathways formed the analytic foundation for formulating mitigation actions and a climate action plan (CAP). The Chinese TA participants received a slightly different TA rollout which replaced the scenario planning workshop with a peaking analysis, in which scenarios, targets, and action plans were developed that would permit a city to reach its peak emissions sooner and at the lowest possible level.

Upon concluding the TA program, a city's delivery partner prepared a summary report. The report documented the delivery process, results from the GHG inventory, key lessons learned from the TA delivery, and a management plan documenting when and how the city would update its inventory.

Despite some variation across cities in the specifics of TA delivery, such as which departments were represented at the workshops, all cities received the same TA program. The only notable difference, as mentioned earlier, was that mainland Chinese cities hosted a peaking analysis workshop instead of a scenario planning workshop. As we discuss below, differences in the "*amount*" of TA received by a city were primarily reflected in whether a city left the program before its completion or joined late and therefore had not completed the program in the timeframe covered by this evaluation.

B. Selection of cities into the GPC TA program and timeline of service delivery

CIFF provided funding to extend the GPC TA program to an initial 30 C40 member cities. Cities were selected for participation to maximize the program's projected impact based on criteria such as mitigation potential, governance capacity to enact climate-smart policies and actions, and ability to develop a GPC-compliant inventory. Selection into the TA program prioritized those cities that in coming years were considered most likely to build new transportation and building infrastructure for which an accurate GHG inventory might push them toward low-carbon design choices.

As the TA program progressed, the composition of participant cities changed.[6] Eight of the original 30 cities ('dropped from intervention') eventually left the program or were removed for various reasons, including inadequate political support, insufficient commitment to the TA program, failure to satisfy C40's membership requirements, and/or rising political instability, among others. Six replacement cities ('added to intervention') that had not made the initial selection took the place of the cities that left the program.[7] There were 22 cities that were selected for participation from the start and have either completed or are expected to complete the full program ('initial intervention' cities). In 2017, CIFF and C40 agreed to reduce the number of TA recipient cities from 30 to 28 and to redirect a portion of project funding to other C40 programs. The TA program was still ongoing at the close of the evaluation period, given the challenges caused by COVID-19, and was expected to conclude in December 2020.

There was not a standardized timetable that applied to all TA recipients; the timing of TA support and its duration varied across cities. In Table II.1, we report on the status of key TA milestones as of Q1 2020, at which time 25 cities had completed gap analyses and GPC workshops, and 10 cities had completed the entire TA program and had submitted their summary reports. C40 expected the submission of a further 17 summary reports by the end of Q2 2020. According to C40 TA program progress trackers, 30 percent of cities that were ever selected to participate in the program either left before receiving TA or received less than a year of TA. Figure II.3 depicts the delivery timeline for the 27 cities that have either completed the program or are continuing to receive services, arranged by service start date. For the 10 cities that fully completed the TA program, an average of 90 weeks (~21 months) elapsed between the start and conclusion of their TA.[8] As the majority of cities had not submitted the summary report by Q1 2020, we also examine the time elapsed between the TA start and the date of a city's GHG inventory audit, which averaged 57 weeks (~13 months). For a few cities, such as Nairobi, Addis Ababa, and Bangkok, the GPC workshop took place several months after MOU signing. In contrast, workshops for other cities such as Lima and São Paulo occurred within a couple months of finalizing MOUs, as demonstrated by the relatively narrow gap between the orange right-pointing triangle denoting MOU signing and the orange circle denoting the GPC workshop date. City-specific political and administrative factors influenced the project timeline for many cities and are one reason for differences in TA engagement durations. While the durations presented in Figure II.3 depict the start and end dates for TA components, cities may have had periods of concentrated TA activity over substantially shorter time periods than displayed.

Table II.1. Status of TA milestone completion as of Q1 2020

Milestone completed	Number of cities
Summary report	10
Scenario workshop	14
GHG inventory audit	21
GPC workshop	25
Gap analysis	25

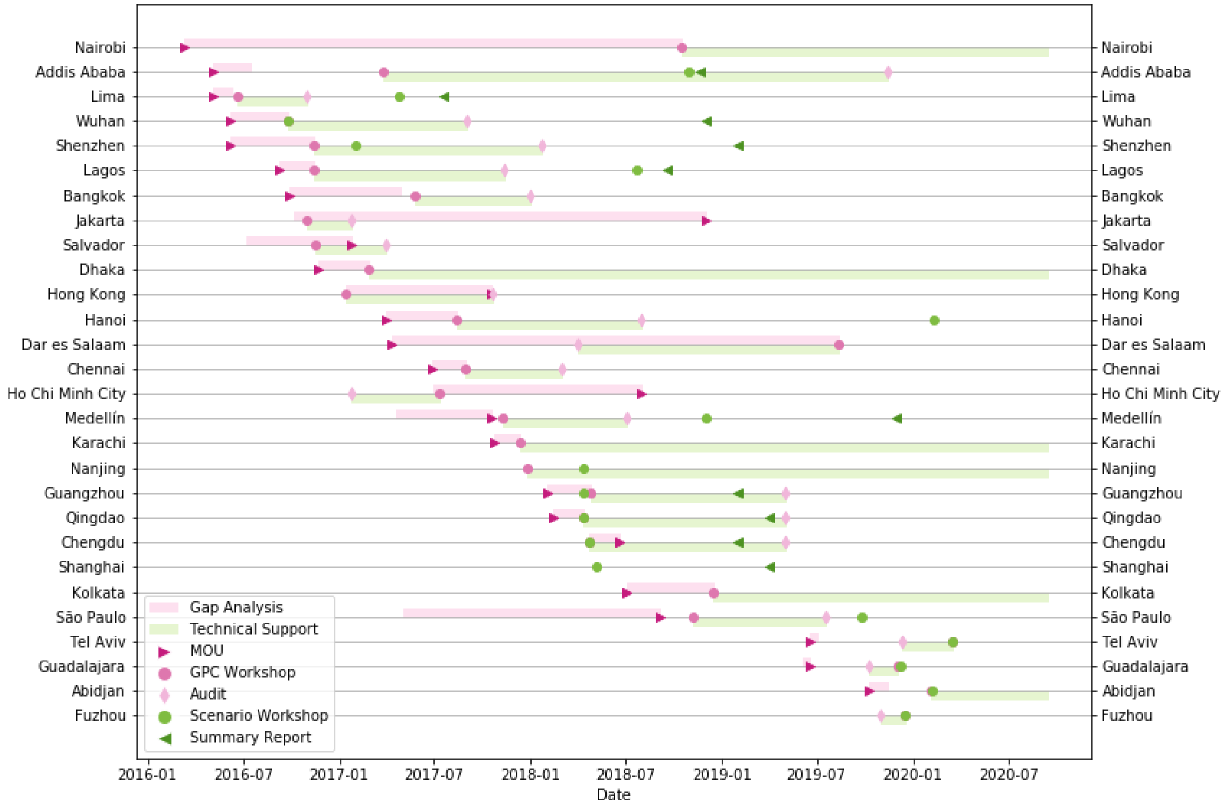
Source: Private correspondence with C40, 17 January 2020.

[6] Throughout this report, we use the term "treatment" to refer broadly to cities that were selected for or participated in the technical assistance program. In Section III.C, we discusses why our research strategy includes questions and analyses that focus only on the initially selected treatment cities and other questions that focus on all cities that ever participated in the TA program.

[7] In Section III, we provide more detail on cities that were added to or dropped from the TA program. In Table A.4, we list the cities that were either removed from or added to the TA program after the program's inception.

[8] Shanghai is the only city of the 10 for which MOU signing and gap analysis completion date data are missing. We instead consider the peaking workshop date to mark Shanghai's TA introduction.

Figure II.3. Timetable of GPC technical assistance implementation



Source: Private correspondence with C40, January 17, 2020.

Note: We depict the gap analysis period as spanning all time between MOU signing and the date C40 lists as when the gap analysis was completed per the C40's Q1 TA progress tracker. We depict cities for which no gap analysis completion date is available as those continuing their gap analysis until the date of the GPC workshop, though in practice a shorter period might have elapsed. Cities whose MOU signing date occurs after the completion dates of other components appear as those records for which the MOU signing is not the earliest outcome in their timeline. Chengdu, Fuzhou, Qingdao, and Wuhan each respectively had their GPC and scenario workshops on the same day. Data are not available on implementation timing for the eight cities initially selected into the TA program but that did not complete the program.

III. Evaluation design, data sources, and estimation approach

Key takeaways of evaluation strategy

- Our final evaluation of the CIFF-funded C40 GPC TA program applies quantitative methods to estimate the program's effect on cities' progress in developing a robust emissions evidence base. This chapter provides more information of these methodologies and introduces outcome measures and data sources.
- This evaluation focuses on three groupings of outcomes: GHG inventories, mitigation actions, and emission reduction targets.
- For most cities, our evaluation relied on data from the two major reporting platforms: CDP and the carbonn Climate Registry (cCR). We use data from C40/WRI and Nangini et al. (2019) to measure outcomes for Chinese cities and comparison cities that do not report to CDP or cCR.
- To assess the impact of TA, we use propensity score matching methods to identify a comparison group that can provide a valid counterfactual for cities selected to receive TA. By comparing changes in outcomes between treatment and comparison cities before and after participating in the TA program, we measure TA's effects, free of other factors that could affect program outcomes.
- Our impact analyses present intent-to-treat (ITT) and treatment-on-treated (TOT) effect estimates. ITT effects measure the impact of selection for TA; TOT effects focus on the impact of the receipt of TA based on cities that complied with their pre-intervention status as a treatment or comparison city.
- We employ a battery of estimation procedures and show how our estimates' direction, magnitude, and precision changed across those procedures. Stable estimates across specifications gives us confidence in their credibility.
- Important limitations to our analysis and our ability to extend its findings to future cohorts of the TA program include a small sample size, the shifting composition of the TA program, the unique characteristics of C40 cities, and C40's participation requirements which helped encourage TA-receiving cities to develop an emissions inventory and climate actions independent of the TA program.

Our final evaluation of the CIFF-funded C40 GPC TA program applies quantitative methods to estimate the program's effect on cities' progress in developing a robust emissions evidence base. If TA program participation effectively alleviated barriers to climate progress by strengthening a city's technical capacity or by connecting city officials with experts who could provide recommendations on inventory completion and mitigation action formulation, then cities receiving TA would have increased their engagement in ambitious climate action.

The four research questions listed in Table III.1 underpin the evaluation strategy and collectively aim to quantify the TA program's impact. In Section III.A, we describe the key outcomes of interest that address the quantity and quality of the three groups of outcomes that flow from the program's theory of change: GHG inventories, mitigation actions, and emission reduction targets. In Section III.B, we provide an overview of the data sources used in the analysis. In Section III.C, we describe our two estimation approaches: descriptive statistics and multivariate regression models.

Table III.1. Summary of evaluation design

Research question	Example outcomes	Estimation approach
RQ1. Do cities that receive the C40-delivered technical assistance produce GPC-compliant emissions inventories and emission reduction targets?	• Reports any GHG inventory • Inventory adopts GPC reporting framework • Reports any mitigation actions	• Descriptive statistics
RQ2. Does receiving technical assistance lead to more rapid and higher quality inventories compared to similar cities that do not receive technical assistance?	• Reports any GHG inventory • Completed or is completing a climate action plan • Reports any emission reduction target	• Multivariate regressions using a matched comparison group design; descriptive statistics
RQ3. Does the technical assistance lead to more and better city climate actions relative to similar cities that do not receive assistance?	• Coverage of emissions scopes • Number of mitigation actions • Number of mitigation action sectors	• Multivariate regressions using a matched comparison group design; descriptive statistics
RQ4. Does reporting a GPC-compliant inventory lead to more and better actions to reduce greenhouse gas emissions relative to similar cities that do not report such an inventory?	• Number of mitigation actions • Reports emission reduction target • Ambitiousness of emission reduction targets	• Descriptive statistics

Note: GHG = greenhouse gas; GPC = Global Protocol for Community-Scale Greenhouse Gas Emission Inventories; RQ = research question.

A. Key outcomes of interest

Our evaluation's primary outcomes of interest capture changes in emissions data reporting or climate policy ambitiousness that would speak to the TA program's effectiveness. We focus on three groupings of outcome reporting: GHG inventories, mitigation actions, and emission reduction targets. All outcomes must be reported in at least one of the data sets we use in our analysis, which include the CDP and cCR data platforms, data shared with the evaluation team from C40 and WRI, and a recently compiled database of city emissions. We assign the timing of each outcome to the time of reporting, not to the dates for when source data were collected or measured.[9] In this section, we describe our approach to constructing the outcomes and elaborate on key decisions that are relevant to their interpretation.[10]

Given that a GHG emissions inventory consists of many subcomponents and may be disaggregated by sector and scope, we construct standardized definitions of an inventory's status based on its satisfaction of specified standards. We categorized a city as reporting an inventory if it submitted any scope-level or sector-level inventory subcomponent to a climate accounting platform in that year. Under our approach, a city that reported in 2018 only its scope 2 emissions to CDP would be counted as reporting an inventory. Similarly, an inventory containing only emissions data for transportation and waste would also be considered a reported inventory under our approach, but, as described below, would be classified as noncomprehensive for its omission of emissions from other sectors such as stationary energy and waste.

[9] Our approach would treat an inventory that was first reported in 2018 but based on activity data collected between January 1 and December 31, 2016, as a 2018 outcome.
[10] Table A.1 provides a complete description of each outcome's construction.

Table III.2. Key outcomes of interest by domain and type

Domain	Outcome type	Outcome
GHG inventory	Reporting	Reports any inventory
		Reports inventory using GPC framework
		Reports inventory that complies with GPC BASIC standards
	Quality	Emissions scope coverage (scope 1, scope 2, and/or scope 3)
		Emissions sectors coverage (emissions from agriculture, industry, stationary energy, transportation, and/or waste)
		Comprehensive coverage of all scopes and sectors
		Reports externally verified inventory
		Reports confidence in inventory
Climate action	Reporting	Reports any mitigation action
		Completed or is completing a climate action plan
	Quality	Number of reported mitigation actions
		Number of sectors for which mitigation actions are reported
Emission reduction target	Reporting	Reports any emission reduction target
	Quality	Reports a Paris Agreement–compliant emissions reduction target

From a technical standpoint, a high-quality inventory is comprehensive across all potential emissions sources, uses the most accurate and recent data available, demonstrates no calculation and/or aggregation errors, and documents all relevant assumptions. A thorough verification of inventory quality would require the replication of the results from and an investigation into all raw input data streams, neither of which fall within the evaluation's scope. Instead, we differentiated high quality inventories according to the comprehensiveness of data reported. We followed WRI et al. (2014a) and used a binary indicator to denote an inventory as *comprehensive* when non-zero values were reported for all five sectors and all three scopes. Cities self-reported the inventory protocol they used and were counted as having produced a *GPC inventory* if their reporting explicitly indicated use of the GPC and followed the data submission fields associated with a GPC inventory.[11] We considered an inventory to be compliant with GPC BASIC standards if it included scope 1 emissions from stationary energy, transportation, and waste; scope 2 emissions from stationary energy and transportation; and scope 3 emissions from waste.[12] We used additional proxies for inventory quality, including whether the city reported high confidence in its submission or if an external party verified the inventory.

We constructed actions and targets similarly. To be considered as specifying a *mitigation action*, a city must have included a unique action description, action area, or action title for any stated actions in a reporting year. Reporting a single action did not equate to an in-place *climate action plan*, which required cities to have explicitly completed or be in the process of completing an action plan per their CDP submission. Since cities only reported the cumulative projected emissions reduction over the lifetime of a climate action in all CDP years prior to 2018, we focus our attention on the number of actions reported and the number of sectors

[11] When completing the CDP questionnaire, reporters can specify which "primary protocol, standard, or methodology" was used to produce an inventory.
[12] Under our approach, cities could attain GPC BASIC compliance by either submitting non-zero emissions subtotals for each of the sectors and scopes required at the BASIC level or prefilling BASIC or BASIC+ emissions data in their CDP submission.

covered by those actions. Without additional information about actions' lifetimes, cross-city comparisons using this information as a proxy for action "quality" would be flawed.[13]

Finally, in earlier work we described a method for assessing the ambitiousness of emission reduction targets against the requirements for complying with the Paris Agreement's goal of limiting temperature increases to 1.5°C (Ward and Thornton 2019). Emission reduction targets in excess of that threshold were categorized as "ambitious."

B. Overview of data sources

No single data set contained information on all cities' reporting outcomes over the period of interest. Therefore, our analysis relied on several sources to build a comprehensive view of city activity on GHG emissions reporting, target setting, and action setting. In Table III.3, we summarize these sources and then describe them in greater detail.

Table III.3. Summary of data sources

Source	Year(s) covered	Key domains	Cities included
CDP	2011-2019	GHG inventories, climate actions, emission reduction targets	All sample cities publicly reporting to CDP through January 2020
carbonn Climate Registry (cCR)	Cumulative to 2018; 2019	GHG inventories, climate actions, emission reduction targets	All sample cities publicly reporting to cCR through January 2020
C40/WRI	2016-2018	GHG inventories, climate actions, emission reduction targets	Sample cities in China
Nangini et al. (2019)	2010	GHG inventories	Sample cities in China
United Nations Population Division	2018	Current and projected population	All sample cities
Kummu et al. (2019)	2015	Gross domestic product (GDP) and Human Development Index (HDI)	All sample cities

For most cities, our evaluation relied on data from the two major reporting platforms: CDP and the carbonn Climate Registry (cCR). We used publicly reported CDP data for the 2011 through 2019 reporting years and supplemented those data with data webscraped from cCR's website to allow for the possibility that cities engaged in climate reporting but did not disclose their information to CDP. To be counted as reporting an inventory, action, or reduction target over a specific time frame, a city need only have reported such an outcome to a single platform. However, outcomes data posted on the cCR website are not as rich as data submitted to CDP, limiting their usefulness in comprehensively addressing the evaluation's research questions. First, the cCR data does not include a reporting year; therefore, we were unable to use it to track reporting trends. Second, cCR data lacks information on inventorying protocols and therefore cannot be used for determining if a city adopted the GPC framework. Third, it captures only scope 1 emissions data and cannot support the construction of indicators for whether a city complied with BASIC requirements.[14] As a result, we prioritized a city's CDP submission when both platforms were used and leverage the cCR data for cities that did not report to CDP.

[13] In 2018, CDP enabled reporters to specify the timescale over which stated emissions reductions would be realized. Since this data is only available for part of the post-TA period, we do not include these outcomes in our analysis.
[14] Further discussion of key differences between CDP and cCR data is available in our Midline and Outcomes memoranda (D'Agostino et al. 2019; Thornton et al. 2019).

We incorporated supplemental data for Chinese cities, who tend not to report publicly to either CDP or cCR. C40/WRI made available private data on GHG inventories, the reporting protocol used, reduction targets, and climate action plans for all 10 Chinese cities receiving TA but did not disclose data from cities not receiving TA.[15] We attempted to remedy the data gap for our comparison cities by incorporating emissions inventory data compiled by Nangini et al. (2019); the authors assembled scope 1 emissions for 83 large Chinese cities based on direct energy consumption statistics for 2010.

Additional data were collected to function as input variables into the propensity score matching procedure used to identify comparison cities not receiving the TA program (described in the next subsection) or to serve as control variables in regression models. We used population data from the United Nations Department of Economic and Social Affairs' "World Urbanization Prospects," which contains current and projected populations for all urban agglomerations with a population exceeding 300,000. Both current population and population growth rates were inputs to our algorithm for determining the ambitiousness of cities' emissions reduction targets (Ward and Thornton 2019). We also included gross domestic product (GDP) per capita and Human Development Index (HDI) values at the city level as potential regression controls (Kummu et al. 2019).[16]

C. Estimation approach

Our evaluation used two types of quantitative analyses: descriptive statistics and multivariate regression analysis using a matched comparison design. We describe both in further detail and explain the conditions under which data availability or reporting outcome prevalence caused one method to be preferable to the other.

1. Descriptive statistics

Descriptive statistics provide a flexible approach to uncovering relationships, changes that develop over time, differences between groups, and continuing gaps in progress. This approach is particularly useful for studying subgroups with a small number of observations, such as cities that report GPC-compliant inventories. Nonetheless, *descriptive statistics cannot isolate the cause of any result that is uncovered.* We cannot use descriptive statistics to determine whether any changes in outcomes resulted from the technical assistance program or other factors, as doing so requires more complex methods which we describe later.

We calculated summary statistics on subgroups as opposed to running multivariate regressions that allow for controlling additional sources of variation across cities (described below). In some settings, we applied descriptive statistics to highlight results for a single group, as when examining treatment cities' reporting outcomes following TA delivery (RQ1). In other settings, we use descriptive statistics with a comparison group to compare outcomes between cities participating in the TA program and those that did not, both before and after TA delivery (RQ2, RQ3). In these instances, we present summary statistics instead of estimating treatment effects. Our analysis of RQ4, comparing outcomes between GPC adopters and non-GPC adopters, exclusively used a descriptive approach because cities' choice of inventory framework did not readily lend itself to an impact analysis approach. In Table III.4, we describe the composition of cities categorized as receiving the TA or GPC "treatment," whereas comparison cities are those that did not.

[15] The most currently available data were compiled in 2018 and include data for the 2016–2018 reporting years.
[16] HDI values are constructed by the United Nations Development Programme (UNDP) as an alternative to GDP to assess development (UNDP 2019). HDI is a composite of the health, education, and economic status of a country and ranges from a low value of 0 to a high of 1.

Table III.4. Description of treatment and comparison cities for descriptive analyses

Descriptive analysis	Treatment cities	Comparison cities
RQ1. All reporting outcomes post-implementation	Cities that were initially selected for TA, including cities that completed or left the program, or cities added to the program as replacement cities	Not applicable
RQ2. Inventory quality before and after implementation	Cities that were initially selected for technical assistance that reported a GHG inventory before or after the program	Matched comparison cities that reported a GHG inventory before or after the program
RQ3. Action quality before and after implementation	Cities that were initially selected for technical assistance that reported mitigation actions before or after the program	Matched comparison cities that reported mitigation actions before or after the program
RQ4. Does reporting a GPC-compliant inventory lead to more and better actions to reduce greenhouse gas emissions relative to similar cities that do not report such an inventory?	Cities that reported a GHG inventory by using the GPC framework in a given reporting period	Cities that reported a GHG inventory by using any other framework in a reporting period

2. Matched comparison group analyses

The cities that CIFF and C40 selected to receive the TA program offer were not chosen at random; they were selected to maximize the possible impact of the program. Consequently, these "treatment" cities could be different from the pool of nontargeted C40 cities in the years before TA delivery. To estimate impacts of the CIFF-funded TA program, we constructed a matched comparison group that resembled as much as possible the characteristics of cities receiving the technical assistance, making the "treatment" and "comparison" cities as similar as possible along dimensions that might be important for determining outcomes. We designed our matched comparison group to provide an indication of how treatment city outcomes would have evolved had the cities not received the TA program and to establish a benchmark for measuring the extent to which TA delivery led to more inventories (RQ2) and more climate actions (RQ3).

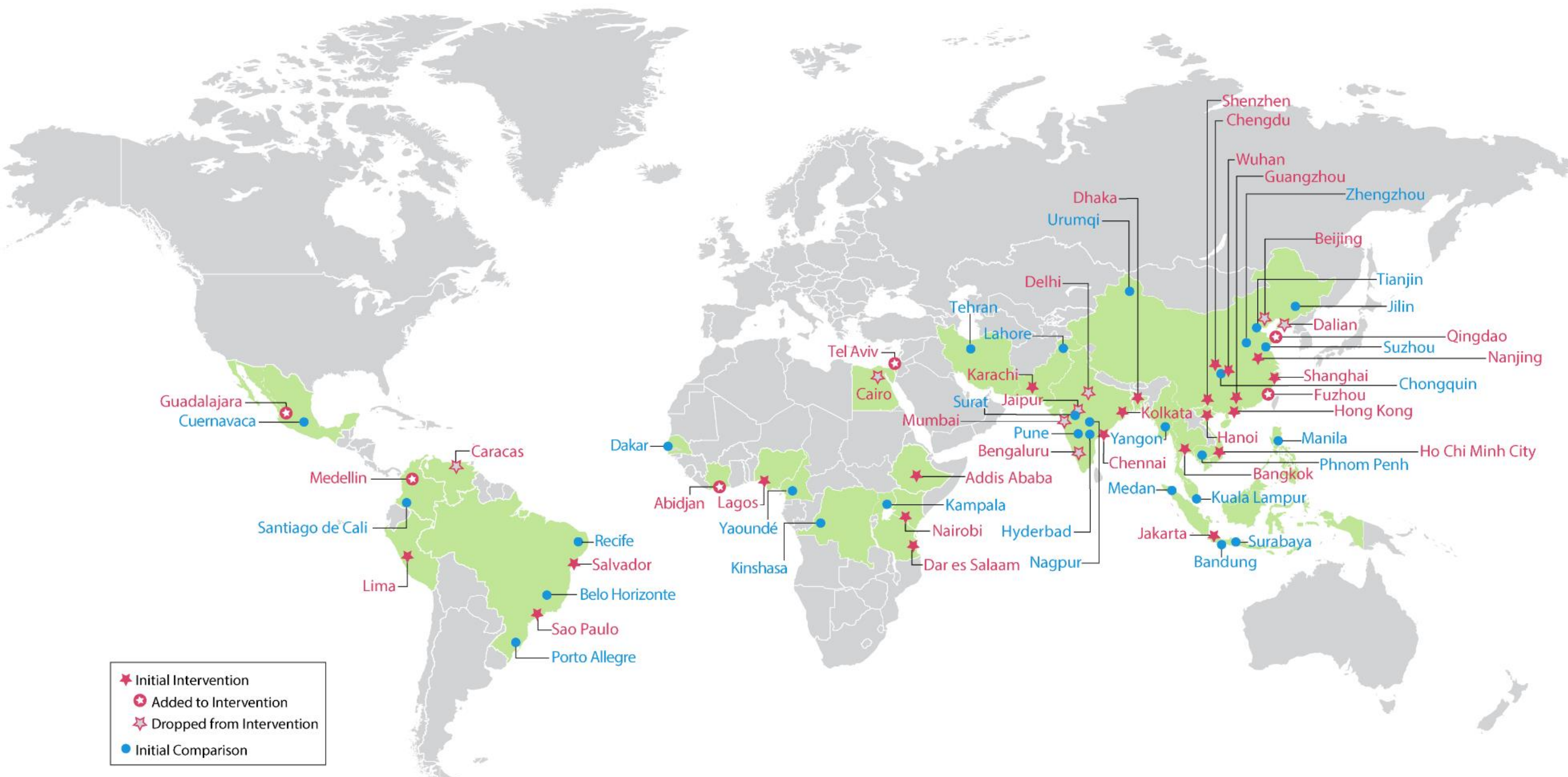
To select cities into the group of comparison cities, we used propensity score matching methods. Propensity scores are the estimated probability of being selected into the treatment group, which in our context is the group of cities selected to receive TA at the outset of the program. Propensity score estimates are constructed by using covariates that capture observable differences in groups' characteristics before the intervention (Rosenbaum and Rubin 1983). Propensity scores compress the several dimensions that might influence a city's ability to complete a GPC inventory, such as GDP per capita or experience in conducting a GHG inventory, onto a unidimensional probability scale that facilitates comparisons between cities selected for TA and cities not selected for TA. By using propensity score estimates to create a comparison group, we can ensure that, for the covariates selected in the matching process, the group of comparison cities more closely approximated the characteristics of the treatment cities than any other possible group of comparison cities. Because factors that could affect emissions reporting are similar between treatment and matched comparison city groups before program implementation (Thornton et al. 2017), we can attribute relative changes in outcomes to the program.

In developing our propensity score model, we first restricted our comparison sampling pool to cities that could have potentially been chosen as an intervention city. We removed from our comparison sampling pool cities that had a population below 500,000 in 2015, that did not have adequate data available, that experienced a high level of social or political conflict at the start of the intervention period, and that were not members of C40 as of January 2016. Then, using our restricted comparison sampling pool and our treatment cities, we compressed the several dimensions that uniquely defined C40 treatment cities (current population, 2000–2010 population growth rate, 2015–2030 projected population growth rate, prior completion of a GHG inventory, country GDP per capita, country greenhouse gas emissions per capita, and UN region) onto a unidimensional scale with a logit model, which assigns each city a propensity score.

Based on the propensity scores, we matched exactly on region, as shown in Figure III.1, and selected the comparison cities that most closely resembled treatment cities. We matched each intervention city with the two comparison cities with the closest propensity scores.[17] We used a matching-with-replacement process that has been shown to reduce bias, especially when comparison blocks have small sample sizes (Dehejia and Wahba 1999).[18]

[17] Table A.2 lists each treatment city with its two nearest neighbor comparison city matches.
[18] Additional details are available in Thornton et al. (2017).

Figure III.1. Map of treatment and comparison cities



3. Difference-in-differences model

We estimated the impact of the assistance on reporting outcomes by using a difference-in-differences (DID) multivariate regression model that compared the outcomes of treatment cities and matched comparison cities over time. We examined two distinct periods over which the outcomes of interest can be measured: the five-year period before the 2016 start of the TA program and the four-year period following the program's launch. Specifically, our model compared the difference in treatment cities' outcomes pre- (2011–2015) and post-intervention (2016–2019) to changes in comparison cities' outcomes over the same periods. Within our sample of treatment and matched comparison cities, changes in comparison cities' reporting outcomes served as a counterfactual for the outcomes expected of treatment cities in the absence of the TA program.

Our preferred regression model for running the DID models is presented in Equation III.1:

Eq. III. 1. $$y_{jk} = \alpha + \beta_1 Treatment_j + \beta_2 Post_k + \beta_3 (Treatment_j x Post_k) + \beta_4 X_{jk} + \varepsilon_{jk}$$

In the model, y denotes the outcome of interest (described in Table III.2 for RQ2 and RQ3) for city j in period k, where k represents either (1) the pre-intervention period or (2) the post-intervention period and j is restricted to our sample of (1) treatment cities or (2) or matched comparison cities. Furthermore, α represents the outcome value for the comparison group pre-intervention; β_1 is the difference in the treatment and comparison groups' outcomes before the start of the TA program; β_2 estimates the change in comparison group outcomes between the pre- and post-intervention periods; and β_3 is our measure of the effect of TA on reporting outcomes, that is, it captures the difference in the differences in treatment and comparison groups' outcome values over time. Finally, our models include controls to absorb city-level differences that may have developed after the matching procedure was conducted, including log population, 2015 HDI values, and indicators for geographic region, all of which are contained in the X vector. Controls for cities' levels of inventory reporting in the post-period are also included when estimating program effects on reporting related to mitigation actions and emission reduction targets.

Our base difference-in-differences model is an unweighted, linear probability model that controls for the city characteristics described above that are most likely to affect the comparability of our treatment and comparison cities. We consider this base model to be the most appropriate for our data and research questions.[19]

4. Treatment effects estimated

Over the course of TA delivery, eight treatment cities left the program, and two cities that were part of our matched comparison group were added to the group of cities receiving C40's TA program. Because not all cities maintained their status as treatment and comparison cities over the period of interest, we separately estimated TA's intent-to-treat (ITT) and treatment-on-the-treated (TOT) effects. ITT effects measure the impact of selection for technical assistance; TOT effects focus on the impact of the receipt of technical assistance based on cities that "complied" with their pre-intervention status as a treatment or comparison city. We estimated these effects by separately running our difference-in-differences models across different groups of treatment and comparison cities, as described in Table III.5.

[19] In all regression models, we use robust standard errors and do not correct for estimating propensity scores before running the main regression (e.g., Austin and Small 2014; Garrido et al. 2014) given the small sample size available.

Table III.5. Treatment and comparison cities for ITT and TOT effect estimates

Effect estimate	Treatment cities	Comparison cities
ITT effects	30 cities initially selected for technical assistance	29 matched comparison cities, selected by the propensity score matching procedure to be most like the 30 cities initially selected for TA
TOT effects	22 cities initially selected for TA that did not drop out of the TA program	27 matched comparison cities, selected by the propensity score matching procedure to be most like the 30 cities initially selected for TA but that did not participate in TA

Note: Table A.3 lists the complete set of cities that comprise the ITT and TOT samples. ITT = intent-to-treat; TA = technical assistance; TOT = treatment-on-the-treated.

TA's ITT and TOT effects may differ, and differences in these effect magnitudes could be indicative of how the partial and full receipt of C40's TA affects reporting outcomes. By construction, the difference between the ITT and TOT effects is the difference between imperfect compliance and perfect compliance with treatment assignment. Observing an estimated TOT effect that is larger than the ITT estimate can be due to differences in their sample compositions and/or because TA has differential effects if received fully versus partially. We cannot rule out the possibility that differences in ITT and TOT effect sizes are driven by differences in the characteristics of ITT and TOT treatment cities or other issues of comparability. For example, it is possible that TOT treatment cities are more committed than ITT treatment cities to reducing GHG emissions. A higher commitment to reducing emissions would motivate TOT cities to have greater participation in TA, to fully receive it when offered, and to increase their likelihood of reporting a GHG inventory; this combination of conditions could result in larger TOT effect estimates. Under this scenario, even if ITT cities were to receive the full TA program, they may not be as likely to report a GHG inventory as the TOT cities.

5. Assessing the robustness of our results

To gauge the sensitivity of our results to our modeling choices, we employed a series of estimation procedures and showed how our estimates' direction, magnitude, and precision changed across those procedures. When an effect is estimated at similar magnitudes across specifications, then we would have more confidence in the credibility of that effect size than if magnitudes were sensitive to specification choices. One such check involved a comparison of outcomes between treatment and comparison cities only in the post-period to account for the possibility that post-period reporting data are of higher quality than pre-period data. Additional robustness checks built on the DID and post-period–only models with and without controls and with and without frequency weights and the number of times a comparison city was matched to a treatment city.[20] Where appropriate, we estimated treatment effects by using a logistic regression—a nonlinear estimation technique designed to analyze binary outcomes. Finally, we observed whether effects varied with and without the inclusion of Chinese cities in our treatment and matched comparison groups. Given that Chinese cities reported emissions data more irregularly and provided less detail, varying their inclusion in a robustness check can test for whether they are the primary cause of any observed effects.

[20] Our k-nearest neighbor propensity score matching procedure allowed comparison cities to serve as a best match for several treatment cities. We included a weighted regression model by using the frequency weights derived from the matching procedure as one of our robustness tests.

D. Methodological limitations and caveats

A key evaluation challenge in measuring the TA program's effects is due to the shifting composition of TA recipients, since substitutions represent a relatively large share of treatment cities. While we addressed this through reporting both ITT and TOT results, the TOT effects do not provide guidance for what treatment effects could be expected if this program were offered to a new group of cities. The ITT estimates would be a preferable benchmark as it already accounts for portfolio-wide imperfect compliance with treatment assignment.

Similarly, the generalizability of our findings to future TA delivery programs hinges on the existence of cities that are similar to TA-receiving cities in characteristics important to setting climate policy. Despite being able to draw from more than 1,200 developing country cities when forming the comparison group, the particularity of the set of treatment cities resulted in the selection of some comparison cities that were determined to be the "best match" for multiple treatment cities. While design choices from our propensity score matching process contributed to this, the exceptionalism of C40 member cities in terms of their population and often capital city status were major factors that limited the set of appropriate comparison cities. Our findings cannot be readily applied to a new batch of cities with substantially smaller populations or different climate reporting histories unless similar matched comparison cities can be identified.

Lastly, C40 members must satisfy the organization's participation standards in order to remain in good standing. Over the 2016—2020 period, the standards included the production of a GPC-compliant city-wide GHG inventory, setting an emission reduction target strategy, and establishing a climate action plan (C40 2016a). <u>It is likely</u> these requirements helped encourage cities to perform those actions independent of their engagement in the TA program.

IV. Impacts of C40's GPC technical assistance program

Key takeaways on impacts of the TA program

- This section address the first three research questions by summarizing the level of treatment cities' post-treatment GHG reporting, using a matched comparison group design to measure the effectiveness of the TA program, and examining the quality of reporting.
- Most cities that ever participated in C40's TA reported GHG emissions inventories, and almost all inventories comply with the GPC framework. A high proportion of cities also reported CAPs, climate mitigation actions, and emissions reduction targets.
- Cities that began the program early and stayed in the program had the highest group-wise completion rates over all outcomes. Average participation levels are, therefore, not representative of the outcomes of cities that complete the program as intended, because reporting is likely to improve as cities that joined TA late complete the program.
- Comparing treatment and comparison cities suggests TA had positive effects on the reporting of GHG inventories and CAPs. The direction of these changes holds across estimation models, which increases confidence in the reliability of these effects. Together, these results support the premise that increasing cities' access to credible emissions data, through increased reporting of GHG inventories, translates into more effective climate action.
- TA had a positive but more modest effect on cities' adoption of the GPC framework, likely because usage of the GPC framework has increased among treatment and comparison cities since program delivery and dampened TA's effect on this outcome.
- TA had small effects on the reporting of mitigation actions and emissions reduction targets; program design, the timing of our evaluation, and political constraints may contribute to this result.
- Descriptive analyses suggest that the GPC's aim of promoting comprehensive reporting of all major emissions was not always achieved in practice. Although about half of treatment cities that reported a GHG inventory complied with GPC BASIC standards, cities often excluded sectors and scopes.
- We find inconclusive evidence related to other aspects of inventory and action quality.

In this section, we present our findings on whether cities that participated in C40's TA program reported more and better inventories, mitigation actions, and emission reduction targets. First, we assess whether cities that ever participated in the program engaged in public reporting of inventories, actions, and targets. Next, we use our matched comparison analysis to isolate TA's effect from other factors affecting cities' emissions data activities and estimate the program's impact on the reporting of inventories, actions, and targets. Finally, we assess changes in the quality of cities' reporting. We examine several facets of reporting quality, including inventory comprehensiveness and the number of sectors covered by mitigation actions.

A. Do cities that receive technical assistance produce GPC-compliant inventories or emission reduction targets?

The majority of cities that ever participated in C40's technical assistance completed the program's immediate objectives of reporting GHG emissions inventories and for those inventories to comply with the GPC framework.

In the period immediately following the start of TA delivery (2016–2019), 50 percent of the 36 cities that received any TA reported a GHG inventory and 42 percent reported an inventory that adopts the GPC framework, as shown in the first row of Table IV.1.[21] The values of these outcomes are similar because almost all cities that reported a GHG inventory reported an inventory adopting the GPC framework. Ever-participating cities' strong preference for basing their reporting on the GPC framework is also shown on Figure IV.1. This figure shows that, in the period immediately following program delivery, only 3 of the 18 ever-participating cities that reported a GHG inventory did not use the GPC framework (Caracas, Delhi, and Hanoi). High adoption of GPC framework is due to first-time reporters using GPC protocols to generate their first inventories (for example, Bangkok, Chennai, and Guadalajara) and to seasoned reporters switching their reporting to this protocol (for example, Ho Chi Minh City, Hong Kong, and São Paolo). Cities were less open to adopting the more stringent GPC BASIC framework, which only 28 percent of cities reported.

Table IV.1. Post-period reporting of inventories, actions, and targets by cities that ever participated in the TA program

Outcome	Number	Percentage of total
Reports any GHG inventory	18	50
Inventory adopts GPC reporting framework	15	42
Inventory complies with GPC's BASIC standards	10	28
Reports any mitigation action	23	64
Completed or is completing climate action plan	21	58
Reports any emissions reduction target	18	55
Number of cities	**36**	

Source: Authors' calculations using data from C40, cCR, CDP, Nangini et al. (2019), and WRI.

Note: Of the 36 cities included on this table, 8 were dropped from the program and 6 were added as replacements. All outcomes are 0/1 binary measures. Values of 1 were applied to all cities that reported that outcome at least once in the post-period years of 2016–2019. Table A.4 provides more detail on cities' individual reporting patterns.

[21] Careful examination of cities reporting behaviors suggests a higher share of cities that ever participated in TA may have taken steps to report an inventory. In addition to the 18 cities that reported a GHG inventory, we find that 10 additional cities were in the process of generating an inventory during the post-period. This implies that only 8 cities that ever received TA took no action toward reporting a GHG inventory. We did not classify cities that in the 2019 reporting period indicated being in the process of completing an inventory as having reported an inventory, because such reports provide no information on actual emissions. It is possible that some of the cities indicating an inventory in process may have completed one for the 2019 reporting period if their TA program had been initiated earlier.

Figure IV.1. GHG inventory reporting of TA program participant cities by inventory accounting framework

Source: Authors' calculations using data from C40, cCR, CDP, Nangini et al. (2019), and WRI.

Notes: Cities included represent all cities that ever participated in the TA program. The pre-period covers CDP's 2011 to 2015 reporting years, whereas the post-period spans 2016–2019. The dotted line indicates the beginning of the post-period. In the pre-period, most of our data on Chinese cities' reporting come from Nangini et al. (2019). We assume a 2013 reporting year for Chinese cities listed in Nangini et al. (2019), based on the average delay between measurement year and reporting year observed in CDP records.

Ever-participating cities also complied with outcomes the TA program intended to advance by strengthening cities' capabilities for producing high-quality GHG inventories. As Table IV.1 shows, 64 and 58 percent of ever-participating cities reported mitigation actions or a CAP, and 55 percent reported any emission reduction targets, which could comprise a city-wide and/or sector-specific focus.

High turn-over among ever-participating cities and resulting differences in the intensity of cities' exposure to the program are key determinant of cities' compliance with TA's outcomes.

Using categorizations described in Section II.B, Figure IV.2 shows that the share of cities that generated a GHG inventory is highest for cities that started the program early ("initial intervention") at 59 percent, falls by 9 percentage points for late entrants ("added to intervention"), and falls further for cities that dropped out of the program. Similarly, Figure II.3, which lists cities in order of when they began engaging with the TA program, shows that early entrants generally participated in the TA program longer than cities added to the program as replacements.[22] Early entrants tended to report multiple inventories in the post-period, whereas several of the late entrants (for example, Chengdu, Abidjan, and Fuzhou) had yet to report an inventory since 2016. Only two cities that that dropped out of the TA program (Caracas and Delhi) reported any post-period inventories. Given a longer evaluation window, it is likely that more of the cities in the "added to intervention" category will report outcomes and narrow the existing gap with the "initial intervention" cities.

The relationship between intensity of participation and outcome completion holds for other key outcome indicators.

Cities that were initially selected for TA participation and who stayed in the program exhibit the highest group-wise completion rates for reporting mitigation actions, CAPs, and emissions reduction targets. This implies that reporting performance across all ever-participating cities will be systematically lower than results achieved by cities that completed the program as intended. Assuming this relationship between reporting outcomes and TA exposure intensity is applicable to cities that had a late start in engaging TA, we anticipate those cities will also achieve high reporting levels after completing the TA program.

[22] Of the replacement cities, only Qingdao and Medellin have received more than one year of TA as determined by their MOU signing dates, by the time the last round of CDP data was collected.

Figure IV.2. Post-period reporting by TA exposure intensity for all cities that ever participated in TA program

Source: Authors' calculations using data from C40, cCR, CDP, Nangini et al. (2019), and WRI.

Notes: All units are expressed as percentages of the number of cities in each category. The respective group counts for "Initial intervention," "Added to intervention," and "Dropped from Intervention" are 22, 6, and 8. "Initial intervention" refers to cities that were initially selected for TA and completed the program. "Dropped from intervention" includes cities that were initially selected for TA but left the program before receiving or completing TA. "Added to intervention" are cities that joined the program as replacement cities. Initial intervention cities received at least one year of TA, if not the full TA package. With the exceptions of Medellin and Qingdao, cities that were added as replacements received less than a year of TA. See Table A.4 for more information on these classifications. Cities were considered to have completed an outcome if they had done so at least once in the post-period years of 2016–2019.

B. Does technical assistance lead to *more* emissions inventories, mitigation actions, and emissions-reduction targets?

The high levels of outcomes reporting that cities achieved after having any level of participation in the TA program is an indicator of success; however, we cannot attribute this result to the effects of the TA program without considering cities' reporting levels had they never received TA.

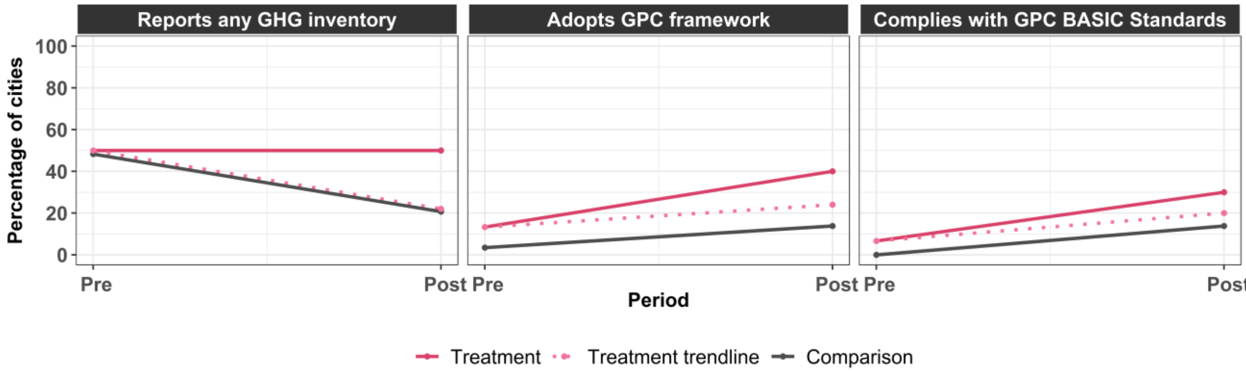
In this section, we use our matched comparison sample and difference-in-differences model to create a credible counterfactual and estimate the effect of TA on reporting. As discussed in Section III.C, our propensity score matching procedure selected the comparison cities that most closely resembled treatment cities according to key variables (for example, population growth and region). Our difference-in-differences model measures program impacts by comparing changes in the outcomes of treatment and comparison cities over time. Changes in comparison cities' reporting before and after the TA provide a measure of how treatment cities would have changed over the same period had they *not* participated in TA. This allows us to distinguish the effects of the TA program from changes that could result from preexisting differences in cities' characteristics, emissions data reporting history, and other factors that affect cities' comparability and willingness to engage in climate policy. Having confirmed that the intensity of cities' exposure to TA influences their reporting, we present treatment estimates using two measures of program impact: intent-to-treat (ITT) effects, focusing on cities initially selected for TA even if they did not complete the program, and treatment-on-the-treated (TOT) effects that are generated from only using data for cities that actually participated in the program as intended.

1. Effects on reporting GHG inventories

C40's TA program enabled TA-receiving cities to achieve a greater level of GHG inventory reporting than is observed among their comparison cities (28 percentage point difference).

Between the pre- and post-periods, the share of comparison cities' reporting of any GHG inventory *fell* from 48 to 21 percent (first panel of Figure IV.3), whereas the share of treatment cities reporting any type of GHG inventory remained stable at 50 percent. Our matched comparison analysis finds that these differences translate into TA increasing the probability of reporting any inventory by 28 percentage points among cities initially assigned to the program, as seen in the first row of Table IV.2. Figure IV.3 shows this effect as the difference between the solid and dotted pink lines in the post-period. The dotted line indicates how treatment cities' reporting would have progressed without selection into TA, by mirroring the slope observed among the comparison cities who did not participate in the TA program. Our TOT effects are similar and associate TA with a 30 percentage point increase in inventory reporting. Because of the small size of our sample, both effects have wide confidence intervals that overlap with zero, and we cannot rule out the null hypothesis of TA having no effect on reporting any GHG inventory.

Figure IV.3. Treatment and comparison cities' reporting of GHG inventories over time



Source: Authors' calculations using data from C40, cCR, CDP, cCR, Kummu et al. (2019), Nangini et al. (2019), UN, and WRI.

Note: All results shown are for the ITT sample. All outcomes are binary variables whose definitions are described in Table A.2. The pre-period covers CDP's 2011 to 2015 reporting years, whereas the post-period spans 2016–2019. The treatment trendline vertically shifts the comparison cities' trend to the treatment cities' pre-TA value to illustrate the estimated treatment. Tables A.5 and A.6 provide more detail on cities' reporting levels in the pre- and post-periods.

TA also had positive effects on treatment cities' likelihood of reporting inventories that adopt the GPC framework (16 percentage points) but had a smaller effect on the share of reported inventories that complied with BASIC standards (10 percentage points) relative to comparison cities.

As seen in the middle and right panels of Figure IV.3, treatment and comparison cities' reporting levels of GPC and BASIC-compliant inventories were comparable at the start of the TA program, with treatment cities respectively at a 10 and 7 percentage point advantage. More cities in both groups reported these inventories over time, and treatment cities' reporting increased more than reporting by comparison cities. Our matched comparison analysis finds that selection into TA increases the probability of reporting an inventory that adopts the GPC framework by 16 percentage points. We estimate a smaller effect for TA's impact on the probability of reporting a BASIC-compliant inventory, at an effect size of 10 percentage points. TA's TOT effects are larger, at 30 and 22 percentage points. Save for the TOT estimate for GPC reporting which is unambiguously positive, the other effects have wide confidence intervals which means that we cannot rule out the possibility of the program having no effect.

Table IV.2. Effects of C40's GPC technical assistance on inventory reporting

	Intent-to-treat effects (n = 118)			Treatment-on-the-treated effects (n = 98)		
	Effect size (1)	Lower bound (2)	Upper bound (3)	Effect size (4)	Lower bound (5)	Upper bound (6)
Reports any GHG inventory	28	-5	60	30	-7	68
	(16)			(19)		
Inventory adopts GPC reporting framework	16	-8	41	30	1	58
	(12)			(14)		
Inventory complies with GPC's BASIC standards	10	-12	31	22	-4	47
	(11)			(13)		

Source: Authors' calculations using CDP, C40, cCR, WRI, Nangini et al. (2019), Kummu et al. (2019), UN data

Note: All units are listed in percentage points. Values in parentheses are standard errors for columns 1 and 4. Our lower and upper bound values mark the endpoints of estimates' 95 percent confidence intervals. The pre-treatment period covers 2011–2015, and the post-treatment period covers 2016–2019. All outcomes are 0/1 binary measures. We consider that cities reported the above-mentioned inventories if they reported these inventories for at least one year belong to a period. We estimate TA's effect sizes over our matched sample of treatment and comparison units (unweighted) with a linear probability model and base difference-in-differences specification (see Section III.C), which includes controls for cities' population levels, HDI, and UN region. The number of observations corresponds to the number of cities that have pre-treatment and post-treatment measures for each outcome of interest. The ITT sample includes 30 treatment and 29 comparison cities, and the TOT sample includes 22 treatment and 26 comparison cities. Table A.3 provides a list of treatment and comparison cities included in our ITT and TOT analyses.

Differences in the effect sizes of inventory reporting outcomes suggest that TA contributes more toward enabling cities to report a GHG inventory than to adopt a specific reporting framework.

Figure A.1 shows that over time the GPC was becoming the preferred reporting framework for both treatment and comparison cities, which we discuss further in Section V. Within both groups, GPC went from being used by 20 percent of cities that reported an inventory in the pre-period to about 80 percent of inventory reporters in the post-period. Repeat reporters who adopt the GPC framework tend to continue using it, with Caracas and Jakarta, who used IPCC frameworks, being exceptions to this pattern.[23] GPC's momentum in becoming the accounting framework of choice among all reporters may explain why the program had smaller effects on this outcome than on inventory reporting more broadly. We estimate TA to be more effective at increasing inventory reporting because unlike GPC adoption, GHG inventory reporting rates were not increasing over time among our comparison group cities. Going forward, TA programs might prioritize removing barriers to inventory reporting over encouraging GPC adoption, as the latter has become mainstreamed.

[23] Cities' annual GHG reporting histories from 2011 through 2019, along with their chosen inventorying methodology, is depicted in Figure A.1.

2. Effects on reporting mitigation actions, climate action plans, and emission reduction targets

TA does not enhance cities' reporting of mitigation actions (7 percentage point effect size, with a wide confidence interval) but is associated with positive changes in the reporting rate of climate action plans (CAPs).

Our matched comparison analysis suggests that being selected into TA increases the probability of reporting any mitigation actions by only 7 percentage points but raises the probability of reporting a CAP by 27 percentage points. TA's TOT effect is larger for both outcomes (15 percentage points for reporting of mitigation action and 33 percentage points for reporting climate action plans), but like our ITT effects it has wide confidence intervals that do not rule out the possibility of a null effect.

Table IV.3. Effects of C40's GPC technical assistance on mitigation action and emission reduction targets

	Intent-to-treat effects (n = 118)			Treatment-on-the-treated effects (n = 98)		
	Effect size (1)	Lower bound (2)	Upper bound (3)	Effect size (4)	Lower bound (5)	Upper bound (6)
Reports any mitigation action	7 (15)	-22	37	15 16	-17	47
Completed or is completing a climate action plan	27 (16)	-5	58	33 (18)	-3	68
Reports any emission reduction target	-4 (16)	-34	27	-4 (17)	-38	30

Source: Authors' calculations using data from C40, cCR, CDP, Kummu et al. (2019), UN, and WRI.

Notes: All values listed are percentage points. The number of observations corresponds to the number of cities that that have pre-treatment and post-treatment measures for each outcome of interest. Our lower and upper bounds mark the endpoints of the 95 percent confidence intervals for the estimates. The pre-treatment period covers 2011–2015 and the post-treatment period 2016–2019. All outcomes are 0/1 binary measures. We consider cities to have reported mitigation actions or climate action plans if they reported those actions for at least one of the years encompassed in a respective period. We estimate TA's effect sizes over our matched sample of treatment and comparison units (unweighted) with a linear probability model using the base difference-in-differences specification (see Section III.C) that includes controls for cities' population levels, HDI, region, and a dummy for whether they reported an inventory in the pre-period (2011–2015). The ITT sample includes 30 treatment and 29 comparison cities, and our TOT sample includes 22 treatment and 26 comparison cities. Values in parentheses are standard errors for columns 1 and 4. Table A.3 provides a list of treatment and comparison cities included in our ITT and TOT analyses.

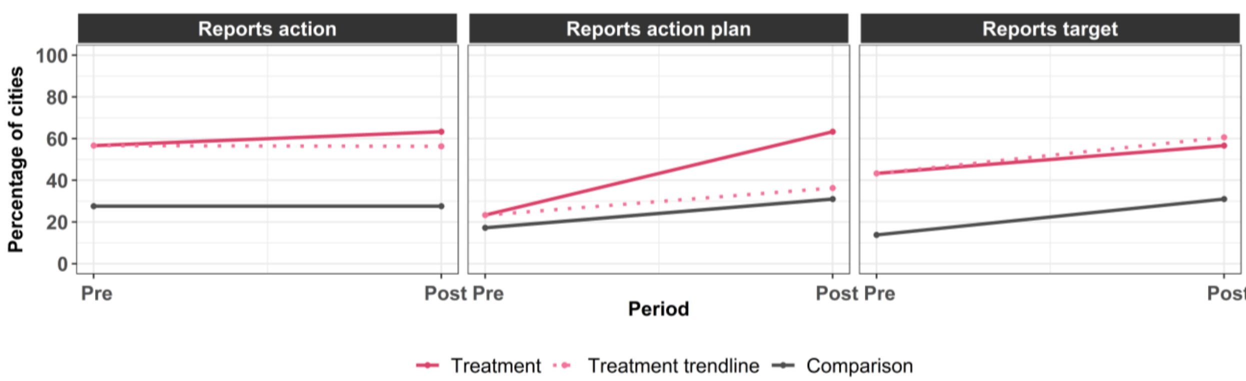
The large spread in effect sizes for the reporting of mitigation actions and for the reporting of CAPs indicates that TA-receiving cities are making progress in formulating mitigation actions, but this may reflect recent changes in C40's participation standards.

Because climate action plans are published documents that describe a portfolio of mitigation actions a city is acting on or plans to undertake, we expect increases in the reporting of action plans to follow increases in the reporting of mitigation actions. Effect sizes for these variables indicate that cities do not follow this pattern, as the reporting of CAPs increased far more than the reporting of mitigation actions. Among treatment cities, the reporting of CAPs increased by 40 percentage points between the pre- and post-periods, whereas the reporting of any mitigation actions grew by only 6 percentage points. Comparison cities follow a similar pattern, but differences in reporting levels are smaller. The disparate growth of cities' mitigation actions and action plans seems to result largely from cities creating action plans aimed at organizing their mitigation actions. For instance, we find that the share of treatment cities reporting mitigation actions *and* action plans rose from 23 percent to 47 percent between periods. However, this does not explain the behavior of about 25 percent of treatment and comparison cities that reported climate action plans *without reporting any mitigation action*. We posit that this group of cities may be responding to C40's participation standards. To maintain their membership in the organization, C40 member cities must satisfy a set of participation standards that encompass requirements such as participating in C40's data collection efforts and attending the C40 Mayors Summit. For 2016–2020, the set of standards included the establishment of "strategic action plans to reduce greenhouse gas emissions and adapt to climate change" (C40 2016a). Treatment cities may have sought to meet this requirement by beginning to prepare plans, even if concrete climate actions had not yet materialized. Because these cities are a minority and we also observe the pattern of CAP reporting without mitigation action reporting among comparison cities, this behavior does not influence our effect estimates. However, our finding does suggest that the level of CAP reporting is rooted in an increased willingness to engage in climate action and to satisfy C40's participation standards. An alternative explanation is that cities are making progress in developing climate action plans that will encompass future mitigation actions and do not reflect existing actions in practice or have simply not reported any actions that are currently being executed.

TA has a slightly negative effect on cities' reporting of emission reduction targets (-4 percentage points) relative to performance observed over time for comparison cities.

Figure IV.4 shows treatment and comparison cities had very different levels of target reporting before TA's delivery (43 and 14 percent). Our matched comparison analysis accounts for this and finds that being selected to TA reduces cities' probability of reporting emissions targets by 4 percentage points (Table IV.3). Our effect size does not change when we adjust for TA program compliance, and wide confidence intervals prevent us from eliminating the possibility that TA had no impact on the setting of emission reduction targets. We do not further examine the effect of TA provision on the setting of ambitious emission reduction targets, because only three cities (Addis Ababa, Kuala Lumpur, and Hong Kong) in any period reported ambitious targets that would be compliant with Paris Agreement emissions pathways.

Figure IV.4. Treatment and comparison cities' reporting of mitigation actions, CAPs, and emission reduction targets over time



Source: Authors' calculations using data from C40, cCR, CDP, Kummu et al. (2019), UN, and WRI.

Notes: All outcomes are binary variables and defined in Table A.1. The pre-period covers CDP's 2011 to 2015 reporting years, while the post-period spans 2016–2019. The figure displays percentages for treatment and comparison cities in the ITT sample. The treatment trendline indicates how outcomes for the treatment group would have changed absent TA service delivery. Tables A.5 and A.6 provide more detail on cities' reporting levels in the pre- and post-periods.

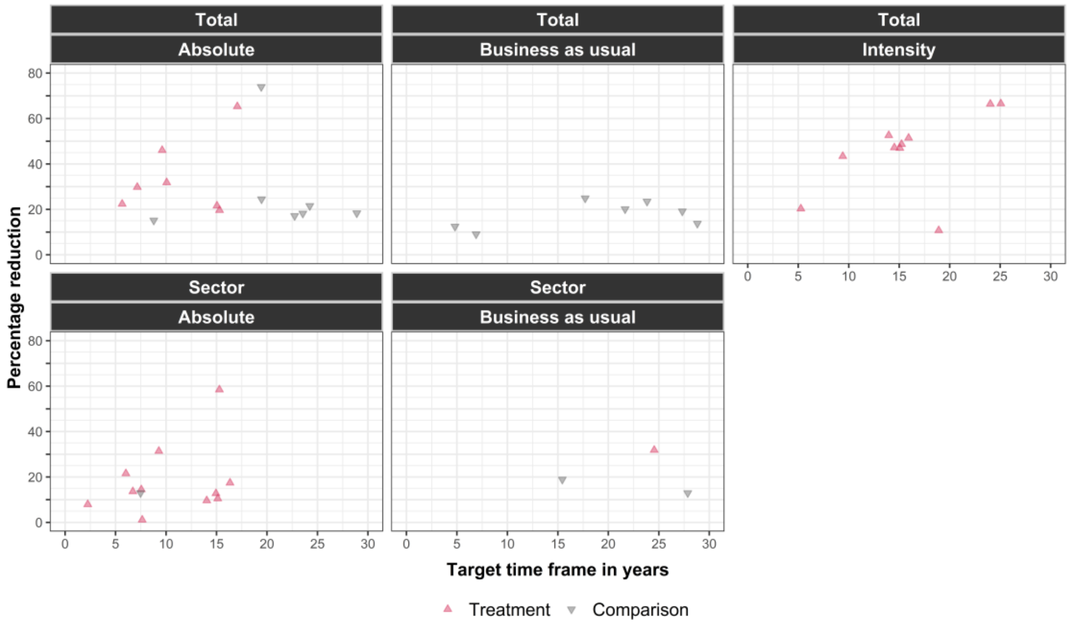
Key factors that may explain the program's small effects on mitigation action and emission reduction targets include the inventory focus of the TA program, the political requirements needed to pursue climate action, and the duration of emission reduction targets. The TA program prioritized increasing cities' reporting of inventories based on the GPC framework. This focus may have encouraged cities to concentrate on inventory completion as an initial step toward advancing climate action and emissions targets. If this is the case, early improvements that are concentrated in inventory reporting would be consistent with the program's design. Improvements in secondary outcomes, such as climate action and emission reduction targets could come later and therefore not be captured by data submitted to CDP through the 2019 reporting period, the last year of data available for this analysis.

It is also possible that cities sought to improve their inventory reporting but stopped short of completing more costly outcomes. For instance, setting an emission reduction target may require public consultation and active support from city agencies outside the department responsible for assembling a GHG inventory, which are costs that are not borne in GHG inventory completion. The provision of TA alone may be insufficient for helping cities overcome these barriers, which may be due to political factors such as the lack of mayoral support or insufficient popular support for climate action (for example, Salon et al. 2014), and not technical or resource capacity limitations.

> **Although growth in comparison cities' reporting of emissions-reduction targets over time surpassed similar growth among the treatment cities (Figure IV.4), we find some support for the claim that treatment cities set more stringent targets.**

Figure IV.5 displays the magnitude of emission reduction target levels reported in the post-period according to the target type used. The vertical axis reports the reduction in GHG emissions in percentage terms, whereas the horizontal axis denotes the number of years until the target is to be achieved (for example, a 2050 target reported in 2015 would be 35 years). Targets may be expressed in absolute terms (for example, "80 percent reduction in annual citywide emissions relative to *2010 levels*"), relative to projected business-as-usual (BAU) levels (for example, "80 percent reduction in annual citywide emissions compared to a *BAU scenario of no additional climate policies*"), or as an intensity-based reduction (for example, "80 percent reduction in annual citywide emissions *per capita*"). Cities may also report targets for their total emissions (top row) or for individual sectors, which would be applicable for all emissions from buildings or from transportation, for example (bottom row).

Figure IV.5. Emission reduction targets by source and target type in the post-period



Source: Authors' calculations using data from C40, cCR, CDP, and WRI.

Notes: The sample depicted includes all ITT cities' targets that were reported in the post-period (2016–2019) that indicated a time frame and emission reduction percentage in any post-period reporting year. "Total" refers to targets that are set for all emission sources. "Sector" targets apply to a specific sector or multiple sectors that are a subset of total city-wide emissions. Targets in the WRI data do not indicate the source, which we classify as "total." Observations are slightly jittered to improve readability.

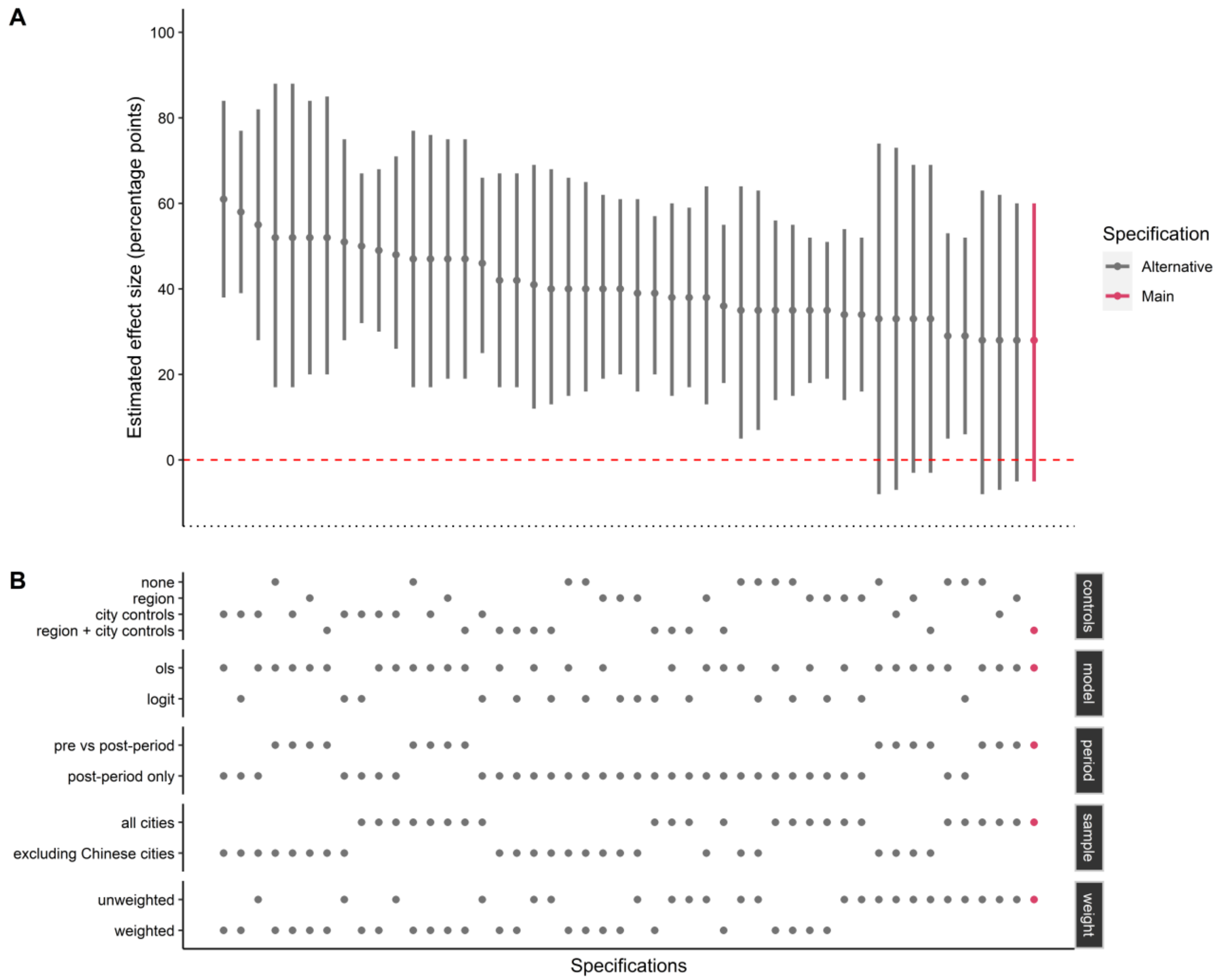
Regardless of which target type is formulated, targets that are ambitious appear in the northwest corner, which represents the locale of large GHG emission reduction values that are slated for achievement in short time frames. In the panel depicting targets applying to a city's "total" emissions that have been formulated using an "absolute" target type, treatment cities' targets tend to be situated more in the northwest region than are comparison cities' targets. This signifies that treatment cities intend to achieve larger reductions in less time. Comparison cities' targets tend to cluster horizontally, such that longer time frames are not associated with deeper emissions cuts. This is especially pronounced for BAU targets set for total citywide emissions. Because emissions pathways compliant with the Paris Agreement require emissions cuts of 80–100 percent by 2050, only the handful of cities with targets exceeding 60 percent that are set with target dates less than 20 years away would come close to Paris-level mitigation.

3. Results of robustness checks and limitations of analysis

As described in Section III.C, we use the results of our base difference-in-differences model to discuss the effect of TA on reporting but conduct additional analyses to test the robustness of these estimates. Figure IV.6 shows how our ITT estimates for reporting any GHG inventory change when we implement the sensitivity checks described in Section III.C.[24] These checks include using a post-period–only model and/or logistic regression to estimate results, varying our model's weighting scheme (that is, include or exclude frequency weights derived from the propensity score matching procedure), including control variables, and using sample compositions. Each point included in the graph represents an effect estimate produced by a different model, with the model specifics indicated in the lower panel. Vertical bars represent the 95 percent confidence intervals for each model. The pink dot and bar denote our base difference-in-differences model results, which are listed in Table IV.2. Our base specification actually depicts the lowest bound for the effect size, meaning that all other regression models estimate a larger estimated effectiveness of TA on GHG inventory reporting. As a result, we are confident that our initially estimated 28 percentage point increase in GHG inventory reporting is not a spurious finding driven by a single specification choice. Although it is true that the confidence interval on this base specification overlaps with zero and prevents us from ruling out a null effect, results from other specifications signify both larger and unambiguously positive effects (that is, no overlap with zero). Those results are indicative of a successful TA program that helped cities increase their GHG inventory reporting rates over time. We find similar support for TA's 16 percentage point effect on the reporting of inventories that adopt the GPC framework (Table A.2).

[24] We include similar figures for all other outcomes of interest in Figures A.2–A.6.

Figure IV.6. Specification plot for GHG inventory reporting regressions



Source: Authors' calculations using data from C40, cCR, CDP, Kummu et al. (2019), UN, and WRI.

Notes: Each specification is identified by a unique combination of model type, controls, periods, samples, and weights. In panel A, each point represents the estimate effect size for a specification type listed below. The gray vertical lines in panel A represent the 95 percent confidence intervals for each specification. The estimated effects in panel A align vertically with each combination of specification factors, which are indicated by points in panel B. Our main specification is shaded in pink.

We conducted similar robustness checks for mitigation action reporting and emission reduction target reporting (not shown) and find roughly consistent effect magnitudes across all models for each outcome type.

For all outcomes other than mitigation action reporting, estimates' confidence intervals span similar ranges and tend to be large. This indicates the large standard errors that result from the small sample size. Our standard errors fare slight better when we include frequency weights, likely because this increases sample size. Using a fixed-effects rather than a difference-in-differences model also reduces our standard errors in some cases. Though there is some variation in this, our estimates don't lead to vastly different conclusions on the possibility of a null effect.

Estimates from our base model capture the lower end of estimate magnitudes and always overlap with zero.

In contrast, specifications that exclude mainland Chinese cities produce larger magnitudes but are not demonstrably different from the full sample models. Having examined the robustness of our findings across a range of alternative models, we believe our selection of the base estimation model is sound but still cannot rule out the possibility that our results may be biased due to unresolved differences between our treatment and comparison groups that also affect the outcomes of interest. Propensity score matching models only balance observable differences for the set of variables selected by the researcher. If our matching model did not account for important unobservable or unmeasurable differences between treatment and comparison groups, such as cities' commitment to reducing GHG inventories, our estimates of the TA's effectiveness may be biased. The analyses we reported in Thornton (2017) guard against this possibility but cannot entirely rule it out. Also, throughout this section, we report large standard errors accompanying the point estimates, which prevents us from being able to conclusively say the TA program had an unambiguously positive effect on our outcomes of interest. As we detail in Section III.C, our standard errors are likely due to the small sample size, which also discouraged us from applying the corrections needed to ensure accurate standard error estimates.

C. Does technical assistance lead to *better* inventories, mitigation actions, and emission reduction targets?

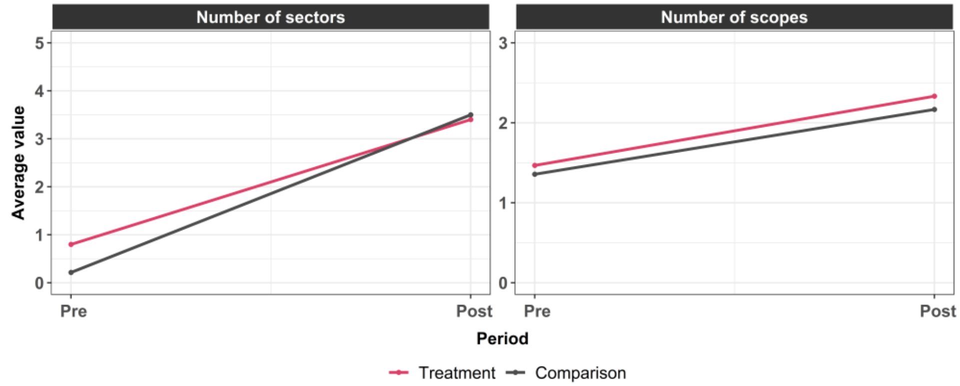
Improving the quality of cities' inventories, actions, and targets is a key objective of C40's technical assistance. Here, we use descriptive statistics to identify changes in the coverage, contents, and confidence in outcomes of interest between treatment and comparison city groups. As we discuss in Section III, we take a descriptive approach to this analysis, in part because the analysis is based on the small sample of cities that reported inventories, mitigation actions, and emission reduction targets. The analyses in this section track the progress of treatment cities (cities originally selected for TA) relative to comparison cities and focus on the subset of cities that reported inventories, actions, or targets for at least one year during the pre- or post-period. Because this group of cities is limited to cities willing to engage in climate action, we cannot generalize our findings beyond these cities. Importantly, we cannot use results from this section to establish expectations of how TA might affect quality were it to be extended to a new group of member cities. We exclude treatment or comparison cities that did not report in either period from group-level averages and similar figures, unless otherwise stated.

1. Quality of greenhouse gas emissions inventories

Descriptive data on inventory quality show that—though treatment and comparison cities' coverage of GHG scopes and sectors remain incomplete, with only one city (Ho Chi Minh City) reporting a comprehensive inventory—both groups have made comparable improvements in inventory coverage.

Between the pre- and post-periods, treatment and comparison cities expanded inventory coverage by an average of about three sectors and one scope, as seen in Figure IV.7. How they achieved the expansion differs across groups. Treatment cities made larger gains in their coverage of scope 2 emissions and reporting agricultural and industrial sectors. Comparison cities underwent the largest gains in their scope 3 emissions reporting and coverage of the waste, transportation, and stationary energy sectors, as shown in Figure IV.8. Each point on Figure IV.8 reports the share of treatment or comparison cities that reported on the scope or sector associated to that point. For instance, the graph on the upper left corner of the figure indicates that about 0 percent of treatment cities reported on the agriculture [forestry, and other land use] sector during the pre-period, and the graph on the upper right corner indicates that about 25 percent of treatment cities reported on this sector in the post-period.

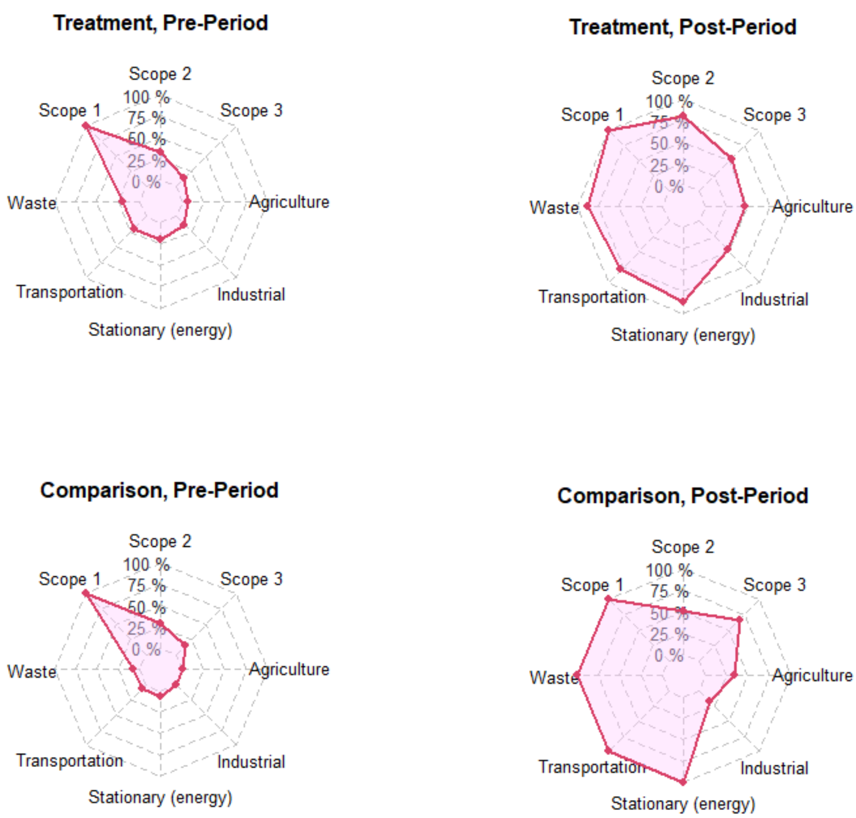
Figure IV.7. Average number of sectors and scopes covered by treatment and comparison cities' GPC inventories over time



Source: Authors' calculations using data from C40, cCR, CDP, Nangini et al. (2019), and WRI.

Notes: All outcomes are continuous variables and defined in Table A.1. The pre-period covers CDP's 2011 to 2015 reporting years, while the post-period spans 2016-2019. Cities included are all ITT sample cities who reported a GHG inventory in any period.

Figure IV.8. Coverage of GHG inventory scopes and sectors for treatment and comparison groups



Source: Authors' calculations using data from C40, cCR, CDP, Nangini et al. (2019), and WRI.

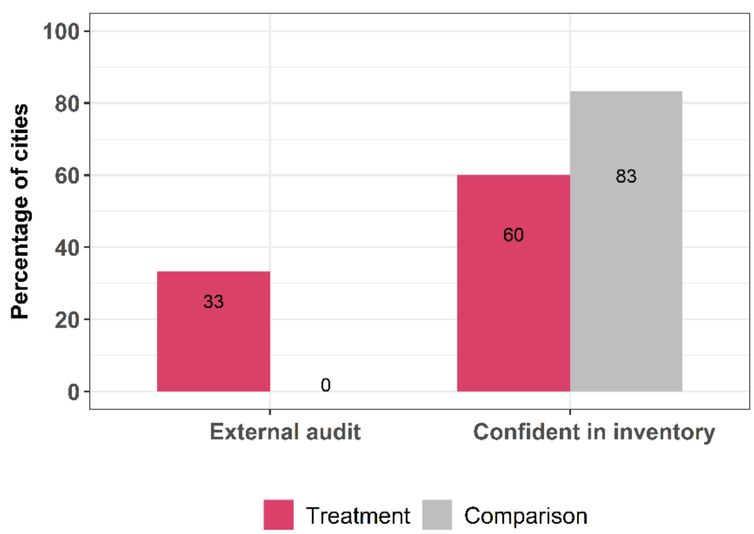
Notes: All outcomes are binary variables defined in Table A.2. The pre-period covers CDP's 2011 to 2015 reporting years, whereas the post-period spans 2016–2019. The figure displays percentages for treatment and comparison cities in the ITT sample that report GHG inventories. The figure shows the proportion of the treatment and comparison group reporting on each scope (scope 1, scope 2, and scope 3) and sector—agriculture, industrial, stationary (energy), transportation, waste—in their

GHG inventories. All reporting outcomes are binary variables defined in Table A.1. The pre-period covers CDP's 2011 to 2015 reporting years, whereas the post-period spans 2016–2019. The figure displays percentages for treatment and comparison cities in the ITT sample that report GHG inventories. The "Treatment, Pre-Period" group and the "Treatment, Post-Period" group both contain 15 cities. Although the "Comparison, Pre-Period" group contains 14 cities, the sample size for "Comparison, Post-Period" drops to 6 cities.

Treatment cities report mixed performance in the quality of their GHG inventories relative to comparison cities, using the completion of external audits and self-reported inventory confidence as proxies for inventory quality.

Figure IV.9 shows a higher share of treatment cities using external audits (33 percentage points higher) to verify inventory accuracy during the post-period, but the treatment cities lag comparison cities by 23 percentage points in indicating high confidence when responding to CDP's question regarding the reporter's "Overall level of confidence" in inventory results. One explanation for treatment cities lower levels of confidence in their inventories is that TA encouraged cities to perceive their inventories' accuracy more critically by helping cities set clear standards for inventory accuracy. We lack the data needed to confirm this possibility. Also, although treatment cities' use of an external auditor may seem promising because this indicator is based on cities presumably taking a concrete action to improve quality rather than perceptions, this indicator may also be capturing C40 program participation if cities consider the inventory review step of the TA program to qualify as an "external audit." We find some support for this, since two of the five cities (Chennai and São Paulo) that reported having conducted external audits indicated that C40 served as their auditor.

Figure IV.9. Treatment and comparison cities' use of external audits and self-confidence in inventory reporting in post-period



Source: Authors' calculations using data from C40 and CDP.

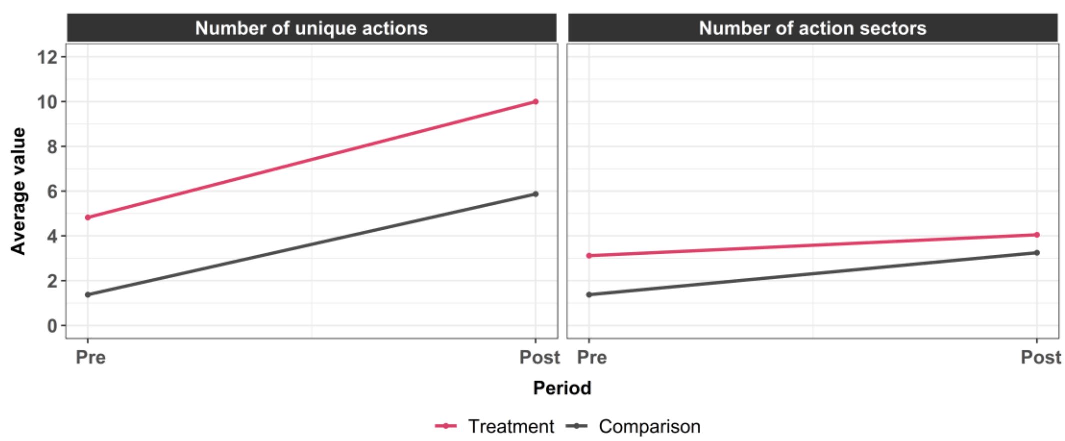
Notes: All outcomes are binary variables whose definitions are described in Table A.1. Questions on cities' confidence in their GHG inventory were only asked in CDP's 2016—2019 reporting years. Questions on external audits were included in all CDP questionnaires from 2011 through 2019. The figure displays percentages for treatment and comparison cities in the ITT sample that reported any GHG inventory.

2. Quality of reported mitigation actions

Treatment cities made important gains in the extent of their mitigation action by achieving broad-based changes in the number of actions they reported.

Figure IV.10 shows treatment and comparison cities achieved comparable increases in the average number of mitigation actions reported and average number of action sectors. Specifically, both groups added about five actions and one action sector to their reporting between the pre- and post-periods. Nonetheless, Figure IV.11 illustrates that treatment and comparison cities differ in how they achieved these changes and reports the change in the number of mitigation action sectors (x-axis) and mitigation actions (y-axis) each sample city reported between the pre- and post-periods. Cities inside the pink quadrant reported more actions and action sectors in the post-period than in the pre-period, whereas cities inside the gray quadrant reported fewer actions and action sectors in the post-period.[25] Cities that made no changes in their reporting are situated at the origin, where the pink and gray quadrants intersect. Between the pre- and post-periods, 19 comparison cities (66 percent), as compared to only 12 treatment cities (44 percent), made no changes in action sectors or action counts. Furthermore, treatment cities increased their average number of actions and sectors through improvements made by several cities, including Jaipur, Jakarta, Nairobi, and Salvador. In contrast, increases in comparison cities' reporting are disproportionately driven by the large improvements made by a single city, Recife. Finally, treatment cities show a slightly stronger pattern of growth in both the number of actions and action sectors covered, as their location to the top and right side of Figure IV.11 suggests. In contrast, comparison cities are concentrated on the lower portion of the top-right quadrant, indicating growth in the number of action sectors reported but limited improvement in the increase of mitigation actions reported between the pre- and post-periods.

Figure IV.10. Average number of actions and action sectors covered by treatment and comparison cities mitigation actions over time

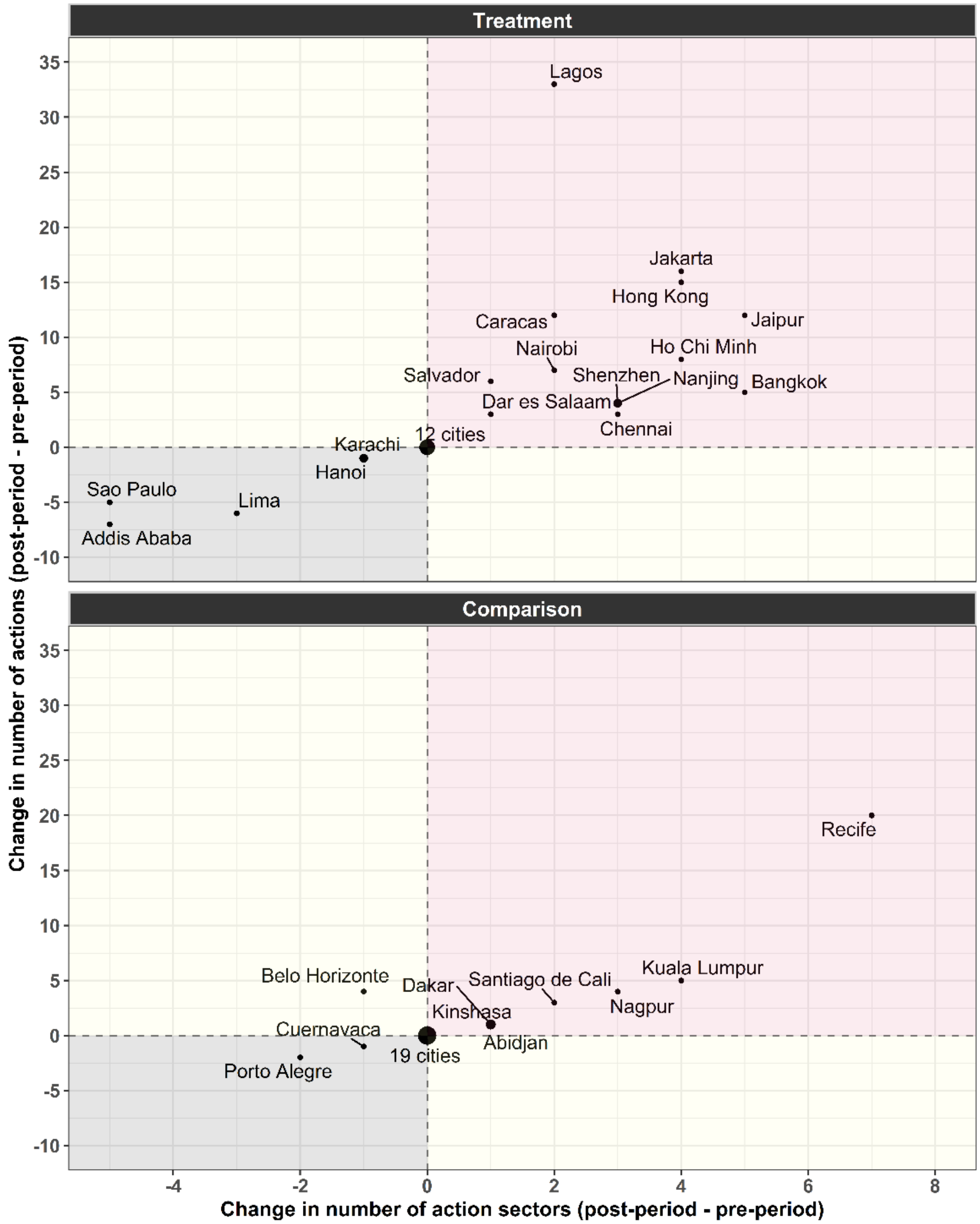


Source: Authors' calculations using data from C40 and CDP.

Note: All outcomes are continuous variables defined in Table A.1. The pre-period covers CDP's 2011 to 2015 reporting years, whereas the post-period spans 2016–2019. The figure displays percentages for treatment and comparison cities in the ITT sample that report mitigation actions.

[25] Belo Horizonte is a unique case in having reported more actions, but fewer action sectors in the post-period.

Figure IV.11. Change in number of actions and sectors covered by each treatment and comparison city's mitigation actions between pre- and post-periods



Source: Authors' calculations using data from C40 and CDP.

Notes: Values represent changes in the number of action sectors (x-axis) and number of actions (y-axis) included in reports between the pre- and post-periods, with positive values denoting increases in reporting activity. The pink quadrant contains cities who report more action sectors and actions in the post-period than in the pre-period. The gray quadrant contains cities who reported fewer action sectors and fewer actions in the post-period than in the pre-period. Cities depicted include those not reporting mitigation actions in either the pre- and/or the post-period. Cities who never reported any mitigation actions would be positioned at the origin. The axes indicate the changes in city-level outcomes from the pre-period to the post-period for continuous variables defined in Table A.1. The pre-period covers CDP's 2011 to 2015 reporting years, whereas the post-period spans 2016–2019.

V. Measuring the effects of GPC adoption

Key takeaways on the effects of GPC adoption

- In this section, we address our fourth research question, which is about whether adopting the GPC as an inventorying methodology helps cities to engage in more and better mitigation actions that would help justify those adoption costs.
- Introduced in 2013, the growing popularity of the GPC as cities' chosen methodology for estimating GHG emissions suggests that cities are, in fact, converging on it as the gold standard accounting framework.
- Cities that use the GPC as their GHG inventory accounting framework are no more likely to report mitigation actions or emission reduction targets than are cities that have calculated their city-wide emissions using a non-GPC methodology.
- Over the 2016 to 2019 CDP reporting years, 79 percent of cities that used the GPC framework in developing their GHG inventory reported at least one mitigation action, which is almost identical to those of non-GPC reporters.
- We find no demonstrable difference in the ambitiousness of emissions reduction targets between GPC adopters and non-GPC adopters across either city-wide or sector-specific targets.
- We also do not find strong evidence that GPC adoption contributes to better mitigation actions or emission reduction targets when assessed by count or number of sectors covered, among those cities that included these components in their emissions data reporting.

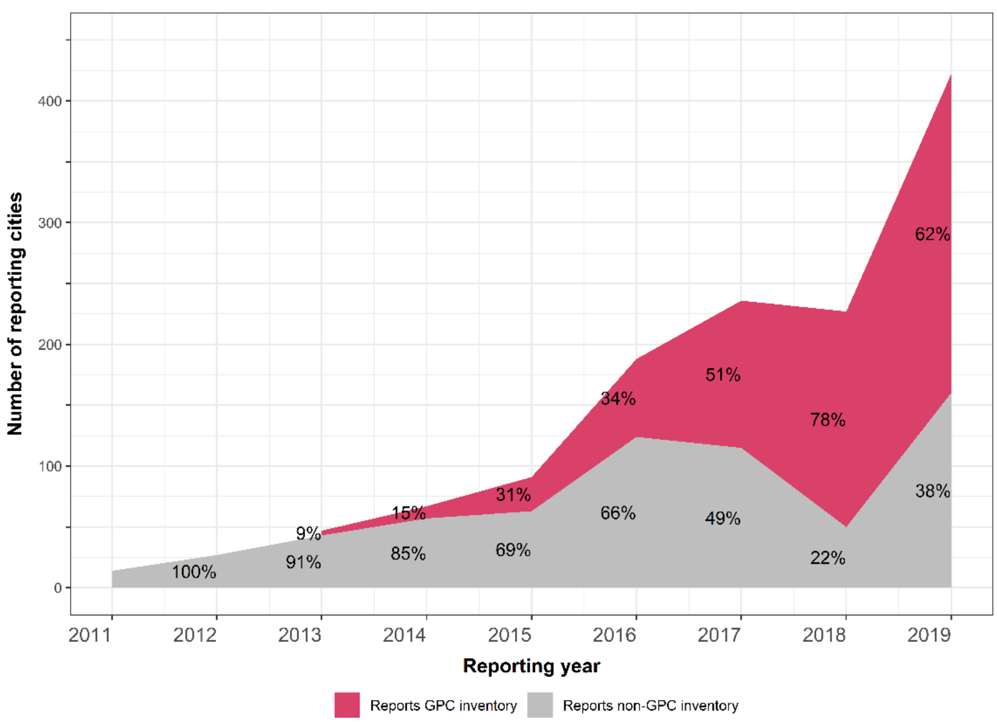
Although the GPC aspires to become the global standard for city-level inventory accounting, at its inception, the GHG Protocol and the pilot cities that initially tested the GPC could not have known how long it would take to achieve that objective or how close to a consensus its adoption would achieve. Decisions like which accounting approach to use are sticky: staff have been trained to use a particular approach, data collection and consolidation systems have been structured around that approach, and deviating from existing practice immediately invalidates benchmarking against prior inventories. The act of switching methodologies involves both tangible and intangible costs and, therefore, would need to generate sizable benefits to be justifiable.

In this section, we address our fourth research question, on whether adopting the GPC as an inventorying methodology helps cities to engage in more and better mitigation actions that would help justify those adoption costs. We use publicly reported CDP submissions to investigate the evidence for any relationship between protocol choice and mitigation actions, looking at both the quantity and quality of mitigation actions and emission reduction targets. When comparing outcomes between GPC and non-GPC adopters, we limit our analysis to the 2016–2019 reporting periods. We believe this choice allows a sufficient sample size, while recognizing that the actions and emission reduction targets posted in more recent years are likely to be substantively different than older submissions when cities were engaging in less ambitious climate action than at present.

We note that any relationships that can be observed between choice of inventorying methodology and climate action are strictly associational and not causal. Cities select which GHG inventorying protocol to use, and any observable differences in outcomes between GPC and non-GPC adopting cities cannot be attributed to GPC adoption. Instead, a confounding variable may drive both and be responsible for any observed relationship. For example, cities whose citizens care more about addressing climate change may prefer using best practices in conducting a GHG inventory and may also support robust climate policy. The attitudes of the citizenry and not the choice of inventorying protocol in this scenario would be responsible for climate policy ambitiousness. Although no causal statement can be made about the effect of GPC adoption on city-level mitigation action, a positive relationship would nonetheless be suggestive and may be cause enough to encourage non-GPC adopting cities to switch.

The GPC first appeared in CDP submissions as a primary emissions calculation methodology in 2013. In that same year, we count cities using more than 20 distinct methodologies, many of which are proprietary and developed specifically for the reporting city. The number of distinct accounting methods has since risen to approximately 30; nevertheless, in 2019, the GPC had a 62 percent market share among city reporters submitting to CDP, as shown in Figure V.1. Since its introduction, the GPC framework has been steadily adopted by an increasing percentage of cities, with 2018's share of 78 percent standing out as anomalously large. Its growing popularity suggests that cities are, in fact, converging on it as the gold standard accounting framework. Furthermore, year-on-year reporting growth across all inventory types has accelerated in recent years, translating to substantial growth in the number of GPC adopting cities. For example, the number of cities reporting GHG inventories using the GPC more than doubled, from 121 in 2017 to 262 in 2019.

Figure V.1. Number and percentage of reporting cities by inventory accounting framework



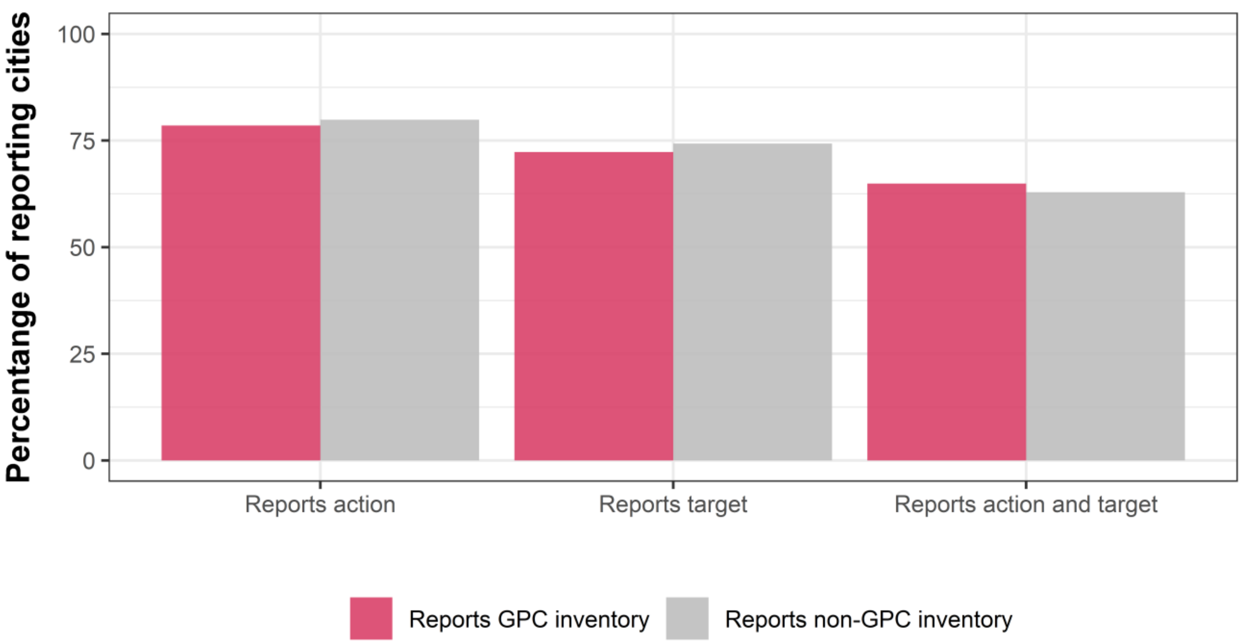
Source: Authors' calculations using CDP 2011–2019.

Note: Sample consists of all cities reporting a city-wide emissions inventory, as defined in Table A.1, in any of the 2011–2019 CDP reporting periods. GPC status is determined by whether a reporter indicated their inventory to be calculated using the GPC or a different methodology in a given reporting year. Inventories that do not indicate a reporting framework are not included in the calculations.

Cities that use the GPC as their GHG inventory accounting framework are no more likely to report mitigation actions or emission reduction targets than are cities that have calculated their city-wide emissions using a non-GPC methodology.

Over the 2016 to 2019 CDP reporting years, 79 percent of cities that used the GPC framework in developing their GHG inventory reported at least one mitigation action, which is almost identical to those of non-GPC reporters, as shown in Figure V.2. Similarly, the percentage of GPC adopters reporting targets, or reporting both a mitigation action and an emissions reduction target, is comparable to the reporting levels observed among cities developing inventories using methods other than the GPC.

Figure V.2. Reporting of climate action and emission reduction targets by inventory accounting methodology



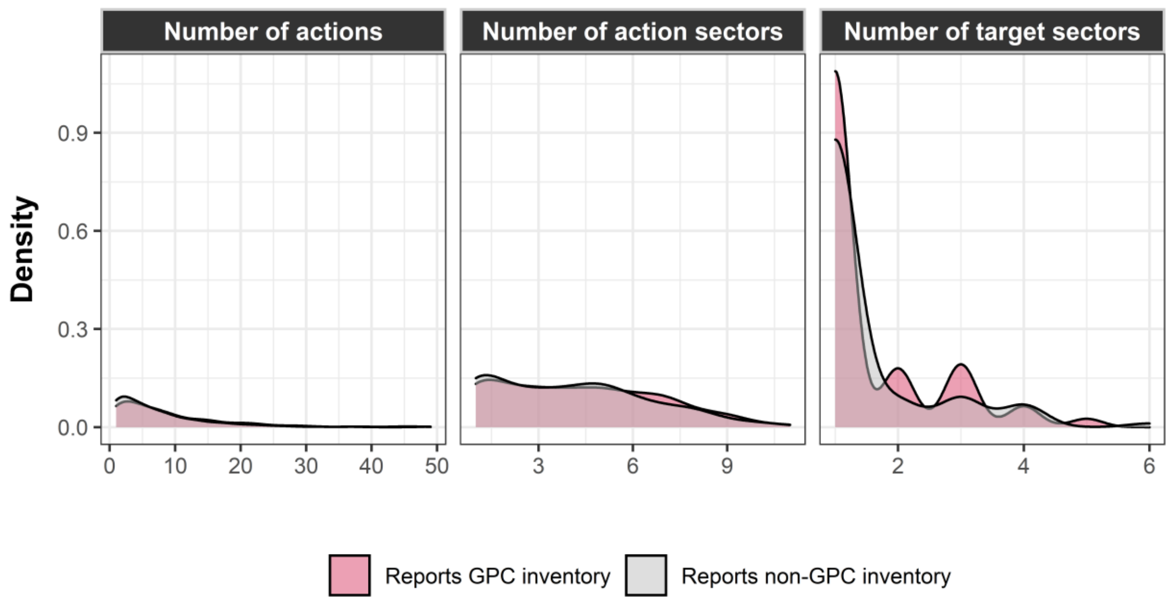
Source: Authors' calculations using CDP 2016–2019.

Note: Sample consists of all cities reporting a city-wide emissions inventory, as defined in Table III.2, in any of the 2016–2019 CDP reporting periods. GPC status is determined by whether a reporter indicated their inventory to be calculated using the GPC or a different methodology in a given reporting year. Inventories that do not indicate a reporting framework are not included in the calculations. Cities with multiple inventories over the period of interest are treated as distinct observations.

We also do not find strong evidence that GPC adoption contributes to better mitigation actions or emission reduction targets when assessed by count or number of sectors covered, among those cities that included these components in their emissions data reporting.

Figure V.3 displays the distribution of all cities that reported a mitigation action and/or reported an emissions reduction target, differentiated by their GPC status, and shows substantial overlap between the two groups. As a result, a comparable percentage of cities in both groups reported the depicted outcomes at any given level of action or target quality. The most notable difference appears in the right-most panel displaying the number of sectors included in a city's emissions reduction target, with visible peaks at two, three, and five sectors. Whereas 22 percent of non-GPC adopters provided more than one target sector, 30 percent of GPC adopters did. Regardless of these differences, the vast majority of either group only provided one emissions reduction target sector, at 70 percent and 78 percent for GPC and non-GPC adopters, respectively. If GPC adoption resulted in more robust mitigation action and target-setting, the pink curves representing the group of GPC adopters would be positioned further to the right of the gray curves and there would be less overlap between the two groups. The solid overlap signifies that there is little relationship between adopting a GPC framework and these examples of climate reporting intensity.

Figure V.3. Distribution of climate action quality outcomes by inventory accounting methodology



Source: Authors' calculations using CDP data for 2016–2019.

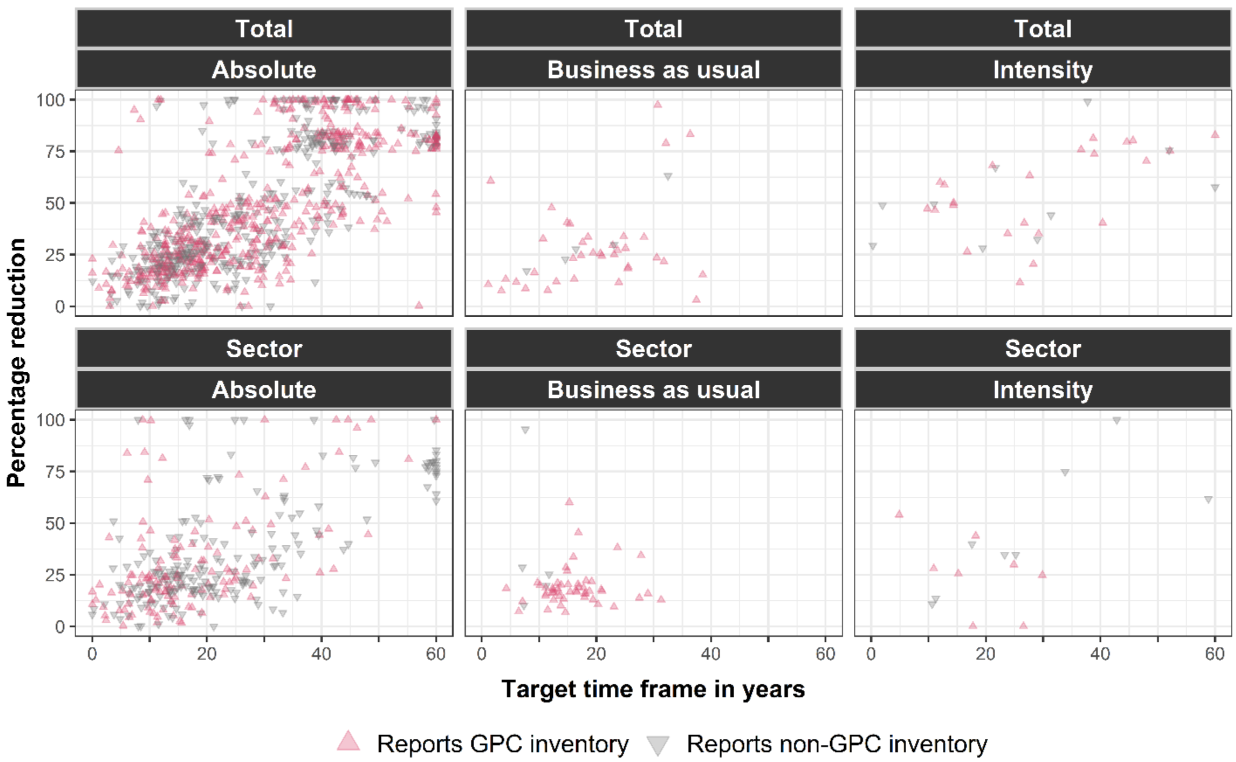
Note: Each kernel density plot represents the distribution of outcomes for all cities reporting a city-wide emissions inventory, as defined in Table A.1, in any of the 2016–2019 CDP reporting periods. All results are conditional on having reported at least one action or emission reduction target. GPC status is determined by whether a reporter indicated their inventory to be calculated using the GPC or a different methodology in a given reporting year. Inventories that do not indicate a reporting framework are not included in the calculations. Cities with multiple inventories over the period of interest are treated as distinct observations. Six cities reporting more than 50 mitigation actions apiece have been censored in the left panel for visual clarity.

We next investigate whether GPC adoption contributes to cities setting more ambitious emissions reduction targets, by comparing the emissions reduction percentages and time frames of GPC adopters with non-GPC adopters. Cross-city comparison is complicated by inconsistencies in the base year, target year, and assumptions about BAU trajectories that cities make when developing their targets (Bansard et al. 2017). We attempt to overcome this by focusing on two key components: the amount of time remaining to achieve the target (for example, a 2050 target included in a 2018 report translates to a 32-year time frame) and the stated emissions reduction percentage. Figure V.4 presents these aspects on the horizontal and vertical axes, with each panel depicting a target type described in Section IV.B.2. Targets that are more ambitious are positioned in the upper left of each panel, where high reduction percentage values coincide with shorter time frames.

We find no demonstrable difference in the ambitiousness of emissions reduction targets between GPC adopters and non-GPC adopters across either city-wide (top row) or sector-specific (bottom row) targets (Figure V.4).

If GPC reporters as a group reported more ambitious targets, the upward-pointing pink triangles would be clustered both above (that is, larger emissions reductions) and to the left of (that is, targets would be achieved in less time) the gray triangles. Although there are stray cases of GPC adopters with exceptionally and potentially implausibly high reduction targets set within a 10-year time frame, the most pronounced of which are in the two absolute target-type panels, we also observe GPC adopters with more modest 50 percent reductions to be achieved in 60 years. Across all reporters, target percentages naturally tend to increase with longer time frames and, therefore, appear as an upward sloping relationship. Of the 845 submissions represented in the top-left panel for city-wide targets using an absolute approach (such as, "City will achieve a 50 percent reduction relative to 1990 levels"), 79 (9 percent) report a target of 100 percent reduction; these include both GPC and non-GPC adopters that cluster at the 2040 and 2050 target years.

Figure V.4. Emission reduction targets reported by inventory accounting methodology



Source: Authors' calculations using CDP data for 2016–2019.

Note: Sample consists of all cities reporting a city-wide emissions inventory, as defined in Table A.1, and at least one emissions reduction target in any of the 2016–2019 CDP reporting periods. GPC status is determined by whether a reporter indicated their inventory to be calculated using the GPC or a different methodology in a given reporting year. Inventories that do not indicate a reporting framework are not included in the calculations. Cities with multiple inventories over the period of interest are treated as distinct observations. Three observations with target time frames exceeding 60 years have been censored for visual clarity.

> **The most notable difference between the two groups lies in their choice of target type, with GPC adopters disproportionately selecting BAU-based targets for both city-wide emissions and individual sectors.**

Although GPC adopters represent 53 of the total sample of cities appearing in Figure V.4 that have submitted any emissions reduction targets, they account for 83 percent of cities reporting BAU targets. In contrast, their representation among cities reporting absolute or intensity-based reductions is more proportional, at 50 and 62 percent respectively. Whereas absolute targets reference some historical year's known emissions, BAU-based targets are framed with respect to the forecast emissions value of the target year under a set of subjective assumptions on economic, population, and carbon intensity growth. For example, these targets may aim for "a 50 percent reduction in emissions in 2050 relative to a business as usual scenario with no additional climate policies." If the assumptions embedded in the BAU forecast are too generous, so that no-policy emissions growth forecasts exceed what would actually happen, cities could misrepresent emissions reductions as more ambitious than they actually are. For example, consider a city of one million people with current GHG emissions of 10 million tons CO_2e (10 tons CO_2e per capita) that forecasts a doubling of their population by 2050. If the city is still undergoing rapid economic growth, they might predict their BAU emissions to be 30 million tons CO_2e in 2050 (15 tons CO_2e per capita). A 50 percent BAU target would be achieved if the city's 2050 emissions are 15 million tons CO_2e. Were the city's population to not double, but only to increase by half, then at the same emissions intensity levels of 15 tons CO_2e per capita, their 2050 emissions would be 22.5 million tons CO_2e (15 tons per capita x 15 million people). A true 50 percent BAU target would therefore be 11.3 million tons, nearly 4 million tons CO_2e less than the target calculated from the more generous BAU emissions level.

VI. Summary and recommendations

We close with a summary of the key findings from our analysis, a set of recommendations for strengthening and monitoring the results of TA delivery, and promising areas for further research.

Key findings

- Eight of the original 30 cities that were selected to participate in the GPC TA program eventually left the program or were removed. Program attrition was driven by various and city-specific reasons, such as inadequate political support, insufficient commitment to the program, a failure to satisfy C40's membership requirements, and/or rising political instability.
- While the TA comprised the same set of supports across all cities, its delivery did not follow a standardized timetable; the timing and duration of TA support varied across recipient cities. As of Q1 2020, 25 cities had completed inventory gap analyses and organized GPC workshops, while 10 cities had completed the entire TA program and submitted their summary reports. For the 10 cities that fully completed the TA program, an average of 90 weeks (~21 months) elapsed between the start and conclusion of their TA.
- The majority of cities that ever participated in C40's TA program completed the immediate objectives (1) of reporting a GHG emissions inventory and (2) for that inventory to have adopted the GPC framework. Cities that were initially selected for program participation and stayed in the program were most likely to have produced a GHG inventory (59 percent of these cities). Cities added to the TA program after the program's start were nine percentage points less likely to have publicly reported a GHG inventory, and cities who dropped out of the program had lower inventory completion rates.
- The TA program contributed to a 28 percentage point higher GHG inventory reporting rate among recipient cities relative to a comparison group composed of similar cities who were not offered TA. TA also had positive effects on cities' likelihood of reporting inventories that adopt the GPC framework (16 percentage point difference), but had a smaller effect on the share of reported inventories that complied with BASIC standards (10 percentage point difference). While inventory comprehensiveness among TA and comparison cities improved over time, as measured by the number of sectors and scopes included in an inventory, there is no noticeable difference in performance between the two groups of cities.
- The effect of TA assistance on mitigation action reporting (7 percentage point difference) is substantially smaller than its effect on CAP reporting (27 percentage point difference). The large spread in these effect sizes indicates that TA-receiving cities are making progress in formulating a portfolio of mitigation actions. However, these changes are unlikely to be exclusively caused by the TA program alone, because C40's participation standards require member cities to publicly report a CAP. Among those cities that reported any mitigation actions, both TA-receiving cities and comparison cities reported an increase in the average number of actions listed.
- Although growth in comparison cities' reporting of emissions reduction targets over time surpassed gains made by treatment cities, there is some evidence that treatment cities set more stringent targets. Only three TA receiving cities (Addis Ababa, Kuala Lumpur, and Hong Kong) in any period reported emissions reduction targets that are substantial enough to be compliant with Paris Agreement emissions pathways. Since the TA program focuses on identifying mitigation actions and developing emission reduction targets only after the inventory has been completed, we anticipate these outcomes will take longer to respond in the CDP data than inventory reporting does.
- Cities that use the GPC as their GHG inventory accounting framework are no more likely to report mitigation actions or emission reduction targets than are cities that have calculated their city-wide emissions using a non-GPC methodology. While GPC adoption rates have climbed over time since it was introduced in 2013, there is little evidence to support the claim that using it as an inventorying methodology leads to more robust mitigation actions or emission reduction targets. As GPC's dominance presumably continues to grow in coming years, its status as the default protocol will be further consolidated, and cities that report their emissions for the first time will be more likely to adopt it.

Recommendations

Our key recommendations for strengthening the outcomes of future TA programs with similar aims to C40's GPC TA program, along with evaluations of such programs, are as follows:

- **C40 should work with its member cities to develop tailored, time-bound roadmaps for remedying the omission of specific sectors and scopes from their inventories.** The gap analysis portion of the TA engagement was intended to identify and resolve data and reporting gaps, but we find that cities receiving TA are still falling short of comprehensive reporting. Only when emissions data is collected for all scopes and sectors will inventories across cities truly be comparable. Among TA-receiving cities that reported a GHG inventory, scope 3 and industrial emissions reporting rates were the lowest among the sectors and scopes that constitute GPC BASIC requirements. We recognize that remedying these data gaps may be resource- and/or time-intensive, and therefore recommend that the time-bound roadmap be responsive to both cities' capacity and C40's prioritization of which data gaps should be addressed first.
- **To achieve all outcomes of the TA program (for example, publicly reporting a GHG inventory, developing an emission reduction target, and producing a CAP) has taken longer than anticipated, which suggests that the evaluation window of future TA programs should be extended to capture the full effects of TA.** While the TA program's theory of change centers on correcting the technical and human resource capacity gaps that inhibit city-level climate action, those challenges are embedded within larger political environments that cannot be exclusively resolved through immediate, technical means. For example, several cities initially selected to receive TA dropped out or were removed from the program because of a lack of political support. This had the effect of delaying delivery to cities that ultimately formed the full set of participating cities. Had the evaluation window been longer, the impacts of TA delivery on all cities could have been captured. Furthermore, we found that TA participants' completion rate of GHG inventories has been higher than for CAPs or emission reduction targets. Because cities who started TA participation early on registered stronger outcomes, we believe that latecomers will also produce expected results if given enough time. However, because of the timing, they were unable to demonstrate those outcomes prior to the CDP 2019 reporting period, which marked the end of data collection for this evaluation.
- **CIFF and C40 should commission a post-TA learning assessment to identify what components of the program and the TA engagement were most/least effective in shifting cities' climate policy-setting capabilities.** This evaluation assessed whether TA participants achieved the TA program's outcomes but can offer limited insight into *why* cities achieved the outcomes they did. Was it because cities had not thought a GPC-compliant inventory was attainable until they received TA, they faced binding staff constraints, the program concentrated their attention on the issue, or because the TA program forged ties across relevant government departments (which was needed in order to access required data streams)? Did the visibility of C40's involvement shift political support for climate policy and, therefore, facilitate the work needed to complete a GHG inventory? We believe that CIFF and C40 would be able to learn much about why the program was a success by engaging city staff who were most closely involved with the program, to hear what they pinpoint as the key success factors. Through those conversations, CIFF and C40 may learn about potentially lighter-touch, more cost-effective alternatives to a complete TA program that might have similar effects of spurring cities into climate action or helping them strengthen existing activities.
- **C40 and other organizations promoting city-level emissions reporting should continue their efforts of coalescing around the GPC as the standard framework for GHG accounting.** Even though we do not find positive evidence between GPC adoption (as opposed to other GHG inventorying methodologies)

and the quantity or diversity of mitigation actions or the magnitude of emission reduction targets, we agree with C40 and the other GPC developers that a consistent measurement approach is crucial to track progress within and across cities. As cities' inventories become more systematically comprehensive, progress tracking will gain further credibility and accuracy. Currently, data gaps render city-wide emissions estimates less meaningful than desired, but it is better for these data gaps to be documented through a common accounting approach. For example, if City A excludes scope 3 emissions, but City B does not, at least their scope 1 and scope 2 emissions can be directly compared. If they were to also use different accounting methodologies, then even the scope 1 and scope 2 comparisons would be uninformative.

- **We encourage cities to share their climate progress on platforms like CDP; the absence of their data and efforts leads to incomplete interpretation and analysis of city-level efforts.** The relatively recent partnership between CDP and cCR in unifying city-level climate reporting has greatly improved access to consistent emissions reporting data, but there are still sizable data gaps. In particular, Chinese cities are engaging in climate action-setting but not uniformly reporting their progress to CDP. We understand that political sensitivities may be one factor discouraging public reporting, but we wish to encourage CIFF, C40, and CDP to identify if there are other factors that might be remedied. Absent a complete capture of city-level inventories and climate actions, researchers and evaluators will only have access to an incomplete view of how much climate progress has been made and how much still must be made in order to comply with Paris Agreement emissions targets.

Areas for future research

While the TA program's focus was to provide a remedy for the technical and resource limitations preventing cities from developing high-quality GHG inventories and climate reporting systems on their own, political and/ or social factors may be the binding constraint to achieving those outcomes for other cities (Ryan 2015). Further research is necessary to develop the diagnostic capability to identify for a given city the most effective 'menu' of interventions that draws on technical, political, social, and/or economic tools. In some contexts, supporting community groups to pressure local politicians may be a sufficient lever for mobilizing city climate policy progress and for cities in turn to allocate appropriate staff and resources. Other cities will simply not have such resources and would benefit from the types of assistance provided by the C40 TA program.

We also think there is significant scope for assessing the role of similar TA programs directed to cities who are not C40 members but who exhibit interest in advancing climate policy efforts. While the nearly 100 cities comprising C40 do include many of the largest cities in the world and collectively account for substantial mitigation opportunities, the vast majority of the world's cities are not C40 members and lack access to the information and networking resources available to members. Ensuring that non-C40 cities also advance decarbonization goals is essential for the world to achieve Paris Agreement targets. Of utmost interest is whether TA programs provided to non-C40 cities can be as effective when not coupled with the city-to-city networks, workshops, and other climate policy contact points afforded through C40 membership.

Appendices

Table A.1. Definition of key outcomes of interest

Outcome group 1: Greenhouse gas emissions inventories	
Reporting outcomes	
Reports any inventory	The city reports a non-zero emission value for any scope-level or sector-level inventory subcomponent on any climate accounting platform for a given reporting year or period. This variable takes a value of 1 if a city reports any inventory and 0 otherwise. When covering a period that is more than one year (e.g., TA's post-treatment period is 2016–2019), it will take a value of 1 if a city reports an inventory for any year included in that period and 0 otherwise.
Inventory adopts GPC reporting framework	As above, but limited to inventories that adopt a GPC framework.
Inventory complies with GPC's BASIC standard [a]	As above, but limited to inventories that comply with GPC's BASIC standards.
Quality outcomes	
Coverage of emission scopes [b]	The city's GHG inventory reports a non-zero emissions value for scope 1, scope 2, and/or scope 3 for a given reporting year or period. We use separate variables to measure cities' coverage of each scope. Variables take a value of 1 if a city's inventory covers that scope and 0 otherwise. This variable is coded as null for cities that do not report GHG inventories, unless otherwise indicated. When covering a period longer than a single year, this variable takes a value of 1 if the city reported for this scope at any time in the period and 0 otherwise.
Coverage of emissions sectors [c]	As above, but measuring coverage of GHG sectors.
Comprehensive coverage of all scopes and sectors	A city's GHG inventory reports non-zero emission values for all scopes and all sectors. This variable takes a value of 1 if a city's GHG inventory covers all scopes and sectors and 0 otherwise. This variable is coded as null for cities that do not report GHG inventories, unless otherwise indicated. When covering a period that is more than one year, the variable will report on the comprehensiveness of the most complete inventory for that period.
Reports externally verified inventory	A city's GHG inventory was externally verified or audited by a third party in a reporting year or period. This variable will take a value of 1 if a city audited its GHG inventory and 0 otherwise. This variable is coded as null for cities that do not report GHG inventories, unless otherwise indicated. When covering a period that is more than one year, this variable takes a value of 1 if the city's inventory was audited in any year and zero otherwise.
Reports confident inventory	A city reports medium or high confidence in the accuracy of its inventory's contents in a reporting year or period. This variable will take a value of 1 if a city reports a high or medium level of confidence in its GHG inventory and 0 otherwise. This variable is coded as null for cities that do not report GHG inventories, unless otherwise indicated. When covering a period that is more than one year, this variable will take a value of 1 if the city expressed confidence in an inventory in any year and zero otherwise.

Outcome group 2: Mitigation actions	
Reporting outcomes	
Reports any mitigation action	A city reports a unique action description, action area, or action title for any stated actions in a reporting year or period. This variable takes a value of 1 if a city reports any mitigation action and 0 otherwise. When covering a period that is more than one year, it will take a value of 1 if a city reports an inventory for any year included in that period and 0 otherwise. In CDP's 2011—2017 reporting periods, actions are labeled as "climate actions" and encompass both mitigation and adaptation activities. We use the mitigation actor sector information listed in the 2018 and 2019 questionnaires to filter out adaptation actions from the 2011—2017 data.
Completed or is completing a climate action plan	The same as above, but measuring whether a city reports having climate action plan or having a climate action plan in progress.
Quality outcomes	
Number of actions [d]	The number of distinct mitigation actions a city sets in a reporting year or period. This variable is coded as null for cities that do not report any mitigation actions, unless otherwise indicated. When covering a period longer than one year, this variable captures the highest number of actions reported in any year.
Number of action sectors	The number of distinct action sectors covered by a city's mitigation actions in a reporting year or period. Potential sectors covered by cites' mitigation actions are not standard and may include transportation, waste, and energy supply. This variable is coded as null for cities that do not report any mitigation actions, unless otherwise indicated. When covering a period longer than one year, this variable captures the highest number of action sectors reported in any individual year.
Outcome group 3: Emission reduction targets	
Reporting outcomes	
Reports any emission reduction target	A city reports an emission reduction target for a given reporting year or period. This variable takes a value of 1 if a city reports an emission reduction target and 0 otherwise. When covering a period that is more than one year, it takes a value of 1 if a city reports an inventory for any year included in that period and 0 otherwise.
Quality outcomes	
Reports ambitious targets	A city reports an emission reduction target that is compliant with the reductions needed to achieve the Paris Agreement's target of limiting temperature increases to 1.5°C. This variable takes a value of 1 if a city reports an ambitious emission reduction target, as described in Ward and Thornton (2019), and 0 otherwise.
Control variables	
GDP per capita	We used OpenStreetMap to determine the centroid GPS coordinates for each sample city and extracted GDP per capita values from their corresponding pixels using 2015 data from Kummu et al. (2019).
HDI	We used OpenStreetMap to determine the centroid GPS coordinates for each sample city and extracted HDI values from their corresponding pixels using data from Kummu et al. (2019).

Note: GDP = gross domestic product; HDI = Human Development Index.

[a] BASIC reporting requirements include the following: scope 1 emissions from stationary energy, transportation, and waste sectors; scope 2 emissions from stationary energy and transportation sectors; and scope 3 emissions from exported waste. We measure BASIC GPC-compliance based on (1) our aggregations of sector and scope emissions combinations and (2) prefilled city-reported

BASIC or BASIC+ emissions in the CDP questionnaire. More specific information on BASIC reporting requirements can be found in WRI et al. (2014a).

[b] Scope 1 refers to GHG emissions coming from sources within a city boundary. Scope 2 GHG emissions refer to emissions emitted from grid-suppled energy sources within a city boundary. Scope 3 includes GHG emissions that occur outside a city boundary but emanate from activities happening within the boundary of that city. Detailed explanations of scope categories can be found in WRI et al. (2014a).

[c] The five main sectors include (1) agriculture, forestry, and other land use (agriculture); (2) industrial processes and product use (industrial); (3) stationary energy; (4) transportation; and (5) waste (WRI et al. 2014a).

[d] The 2019 CDP questionnaire asks cities to "Describe the anticipated outcomes of the most impactful mitigation actions your city is currently undertaking; the total cost of the action, and how much is being funded by the local government." The number of actions a city report is likely to reflect a city's willingness to engage in climate action but may not include all actions the city is taking to mitigate emissions.

Table A.2. Comparison cities matched to intervention cities through propensity score matching

Treatment city	First comparison city match	Second comparison city match
Addis Ababa	Kinshasa	Abidjan
Cairo	Kinshasa	Abidjan
Dar es Salaam	Kampala	Yaoundé
Lagos	Kinshasa	Abidjan
Nairobi	Abidjan	Dakar
Beijing	Chongqing	Tianjin
Chengdu	Qingdao	Urumqi
Dalian	Jilin	Zhengzhou
Guangzhou	Chongqing	Tianjin
Hong Kong	Tianjin	Chongqing
Nanjing	Qingdao	Urumqi
Shanghai	Chongqing	Tianjin
Shenzhen	Chongqing	Tianjin
Wuhan	Tianjin	Suzhou
Bengaluru	Pune	Surat
Chennai	Pune	Surat
Delhi	Surat	Pune
Jaipur	Hyderabad	Nagpur
Kolkata	Surat	Pune
Mumbai	Surat	Pune
Caracas	Cali	Recife
Lima	Belo Horizonte	Recife
Salvador	Porto Alegre	Cuernavaca
Sao Paulo	Belo Horizonte	Recife
Bangkok	Kuala Lumpur	Surabaya
Hanoi	Yangon	Phnom Penh
Ho Chi Minh City	Manila	Bandung
Jakarta	Manila	Bandung
Dhaka	Tehran	Lahore
Karachi	Tehran	Lahore

Notes: We used the results of our propensity score model to match each treatment city with the two comparison cities that most closely resemble it. Because we used matching-with-replacement, some comparison cities matched to more than one treatment city. Because we matched perfectly on region, all treatment cities and their comparison city matches are from the same region.

Table A.3. Treatment and comparison cities for intent-to-treat and treatment-on-the-treated effect estimates

Effect estimate	Treatment cities		Comparison cities	
Intent-to-treat effects	Addis Ababa	Hong Kong	Abidjan	Porto Alegre
	Bangkok	Jaipur	Bandung	Pune
	Beijing	Jakarta	Belo Horizonte	Qingdao
	Bengaluru	Karachi	Chongqing	Recife
	Cairo	Kolkata	Cuernavaca	Santiago de Cali
	Caracas	Lagos	Dakar	Surabaya
	Chengdu	Lima	Hyderabad	Surat
	Chennai	Mumbai	Jilin	Suzhou
	Dalian	Nairobi	Kampala	Tehran
	Dar es Salaam	Nanjing	Kinshasa	Tianjin
	Delhi	Salvador	Kuala Lumpur	Urumqi
	Dhaka	Sao Paulo	Lahore	Yangon
	Guangzhou	Shanghai	Manila	Yaounde
	Hanoi	Shenzhen	Nagpur	Zhengzhou
	Ho Chi Minh City	Wuhan	Phnom Penh	
Treatment-on-the-treated	Addis Ababa	Karachi	Bandung	Porto Alegre
	Bangkok	Kolkata	Belo Horizonte	Pune
	Chengdu	Lagos	Chongqing	Recife
	Chennai	Lima	Cuernavaca	Santiago de Cali
	Dar es Salaam	Nairobi	Dakar	Surabaya
	Dhaka	Nanjing	Hyderabad	Surat
	Guangzhou	Salvador	Jilin	Suzhou
	Hanoi	Sao Paulo	Kampala	Tehran
	Ho Chi Minh City	Shanghai	Kinshasa	Tianjin
	Hong Kong	Shenzhen	Kuala Lumpur	Urumqi
	Jakarta	Wuhan	Lahore	Yangon
			Manila	Yaounde
			Nagpur	Zhengzhou
			Phnom Penh	

Notes: The ITT sample includes 30 treatment and 29 comparison cities and the TOT sample includes 22 treatment and 27 comparison cities. Eight cities in the ITT treatment group are not included in the TOT treatment group (Beijing, Bengaluru, Cairo, Caracas, Dalian, Delhi, Jaipur, and Mumbai) because they left the program before receiving C40's full course of TA, if any. Two cities in the ITT comparison group are not included in the TOT comparison group (Abidjan, Qingdao) because they were included in the program as replacements for the cities that left the TA program.

Table A.4. Post-period reporting by cities that ever participated in C40's TA program

City	Participation in TA	Reports any GHG inventory	Inventory adopts GPC reporting framework	Inventory complies with GPC's BASIC standards	Reports any mitigation action	Completed or is completing climate action plan	Reports any emissions reduction target
Addis Ababa	Initial intervention	Yes	Yes	Yes	Yes	Yes	Yes
Bangkok	Initial intervention	Yes	Yes	No	Yes	Yes	Yes
Chengdu	Initial intervention	No	No	No	No	Yes	Yes
Chennai	Initial intervention	Yes	Yes	Yes	Yes	Yes	Yes
Dar es Salaam	Initial intervention	No	No	No	Yes	Yes	Yes
Dhaka	Initial intervention	No	No	No	Yes	Yes	No
Guangzhou	Initial intervention	No	No	No	No	Yes	Yes
Hanoi	Initial intervention	Yes	No	No	Yes	No	No
Ho Chi Minh City	Initial intervention	Yes	Yes	No	Yes	Yes	No
Hong Kong	Initial intervention	Yes	Yes	Yes	Yes	Yes	Yes
Jakarta	Initial intervention	Yes	Yes	No	Yes	Yes	Yes
Karachi	Initial intervention	No	No	No	No	No	No
Kolkata	Initial intervention	Yes	Yes	Yes	No	No	No
Lagos	Initial intervention	Yes	Yes	Yes	Yes	Yes	No
Lima	Initial intervention	Yes	Yes	Yes	Yes	Yes	Yes
Nairobi	Initial intervention	No	No	No	Yes	No	No
Nanjing	Initial intervention	No	No	No	Yes	Yes	Yes
Salvador	Initial intervention	Yes	Yes	Yes	Yes	No	No
Sao Paulo	Initial intervention	Yes	Yes	Yes	Yes	Yes	Yes
Shanghai	Initial intervention	No	No	No	No	Yes	Yes
Shenzhen	Initial intervention	No	No	No	Yes	Yes	Yes
Wuhan	Initial intervention	Yes	Yes	Yes	Yes	Yes	Yes
Beijing	Dropped from intervention	No	No	No	No	Yes	Yes
Bengaluru	Dropped from intervention	No	No	No	No	No	No
Cairo	Dropped from intervention	No	No	No	No	No	No

City	Participation in TA	Reports any GHG inventory	Inventory adopts GPC reporting framework	Inventory complies with GPC's BASIC standards	Reports any mitigation action	Completed or is completing climate action plan	Reports any emissions reduction target
Caracas	Dropped from intervention	Yes	No	No	Yes	No	No
Dalian	Dropped from intervention	No	No	No	No	No	Yes
Delhi	Dropped from intervention	Yes	No	No	No	Yes	Yes
Jaipur	Dropped from intervention	No	No	No	Yes	No	No
Mumbai	Dropped from intervention	No	No	No	No	No	No
Abidjan	Added to intervention	No	No	No	Yes	No	No
Fuzhou	Added to intervention	No	No	No	No	No	No
Guadalajara	Added to intervention	Yes	Yes	No	Yes	Yes	No
Medellin	Added to intervention	Yes	Yes	No	Yes	Yes	Yes
Qingdao	Added to intervention	No	No	No	No	No	Yes
Tel Aviv	Added to intervention	Yes	Yes	Yes	Yes	No	Yes

Source: Authors' calculations using data from C40, cCR, CDP, Nangini et al. (2019), and WRI.

Notes: "Initial intervention" refers to cities that were initially selected for TA and completed the program. "Dropped from intervention" are cities that were initially selected for TA but left the program before receiving or completing TA. "Added to intervention" are cities that joined the program as replacement cities. Cities that were initially selected for TA and did not drop out of the program received at least one year of technical assistance, if not the full TA package. With the exceptions of Medellin and Qingdao, cities that were added as replacements received less than a year of technical assistance. Twenty-two ever-participating cities are "Initial Intervention," six were "Added to Intervention," and eight were "Dropped from Intervention." See Figure II.1 for more information on these classifications. We consider that cities that completed the outcomes included in this table reported these inventories for at least one year corresponding to the post-treatment period (2016–2019).

Table A.5. Pre- and post-reporting by treatment and comparison cities included in intent-to-treat analyses

	Treatment cities (n = 30)			Comparison cities (n = 29)		
	Pre-period	Post-period	Difference	Pre-period	Post-period	Difference
Reports any GHG inventory	50%	50%	0%	48%	21%	-28%
Inventory adopts GPC reporting framework	13%	40%	27%	3%	14%	10%
Inventory complies with GPC's BASIC standards	7%	30%	23%	0%	14%	14%
Reports any mitigation action	57%	63%	7%	28%	28%	0%
Completed or is completing climate action plan	23%	63%	40%	17%	31%	14%
Reports any emissions reduction target	43%	57%	13%	14%	31%	17%

Source: Authors' calculations using data from C40, cCR, CDP, Nangini et al. (2019), UN, and WRI.

Note: This table shows cities' levels of reporting during the pre- and post-periods. Though these figures serve as the base for our difference-in-differences models, the raw difference between the changes each group achieved over time are not equal to our effect estimates. This is the case because our difference-in-differences model includes controls that account for region- and city-level differences. All units are listed as a percentage of the total amount of cities in each group.

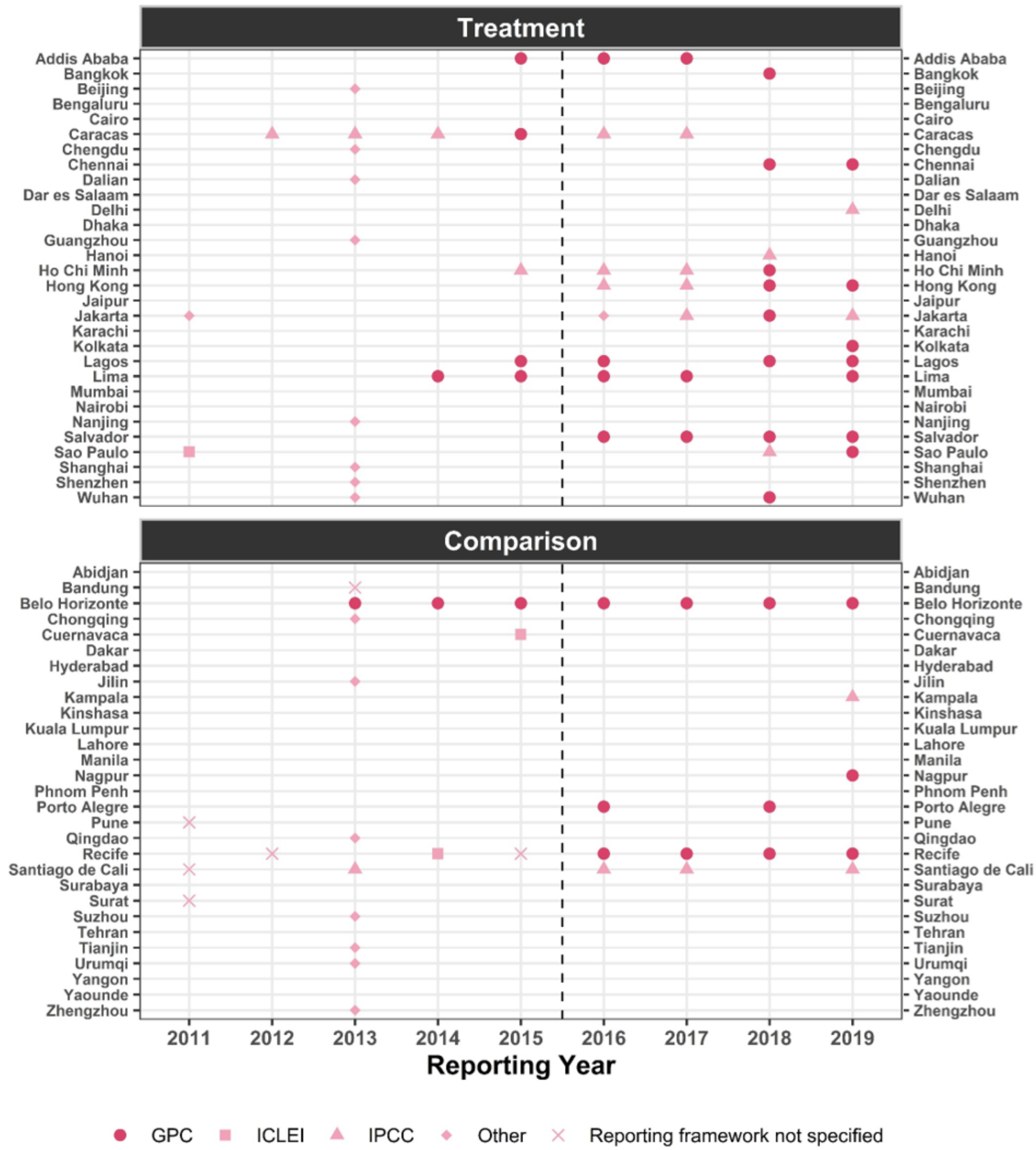
Table A.6. Pre- and post-reporting by treatment and comparison cities included in treatment-on-the-treated analyses

	Treatment cities (n = 22)			Comparison cities (n = 27)		
	Pre-period	Post-period	Difference	Pre-period	Post-period	Difference
Reports any GHG inventory	55%	59%	5%	48%	22%	-26%
Inventory adopts GPC reporting framework	14%	55%	41%	4%	15%	11%
Inventory complies with GPC's BASIC standards	5%	41%	36%	0%	15%	15%
Reports any mitigation action	68%	77%	9%	30%	26%	-4%
Completed or is completing climate action plan	32%	77%	45%	19%	33%	15%
Reports any emissions reduction target	50%	64%	14%	11%	30%	19%

Source: Authors' calculations using data from C40, cCR, CDP, Nangini et al. (2019), UN, and WRI.

Notes: This table shows cities' levels of reporting during the pre- and post-period. Though these figures serve as the base for our difference-in-differences models, the raw difference between the changes each group achieved over time are not equal to our effect estimates. This is the case because our difference-in-differences model includes controls that account for region- and city-level differences. All units are listed as a percentage of the total amount of cities in each group.

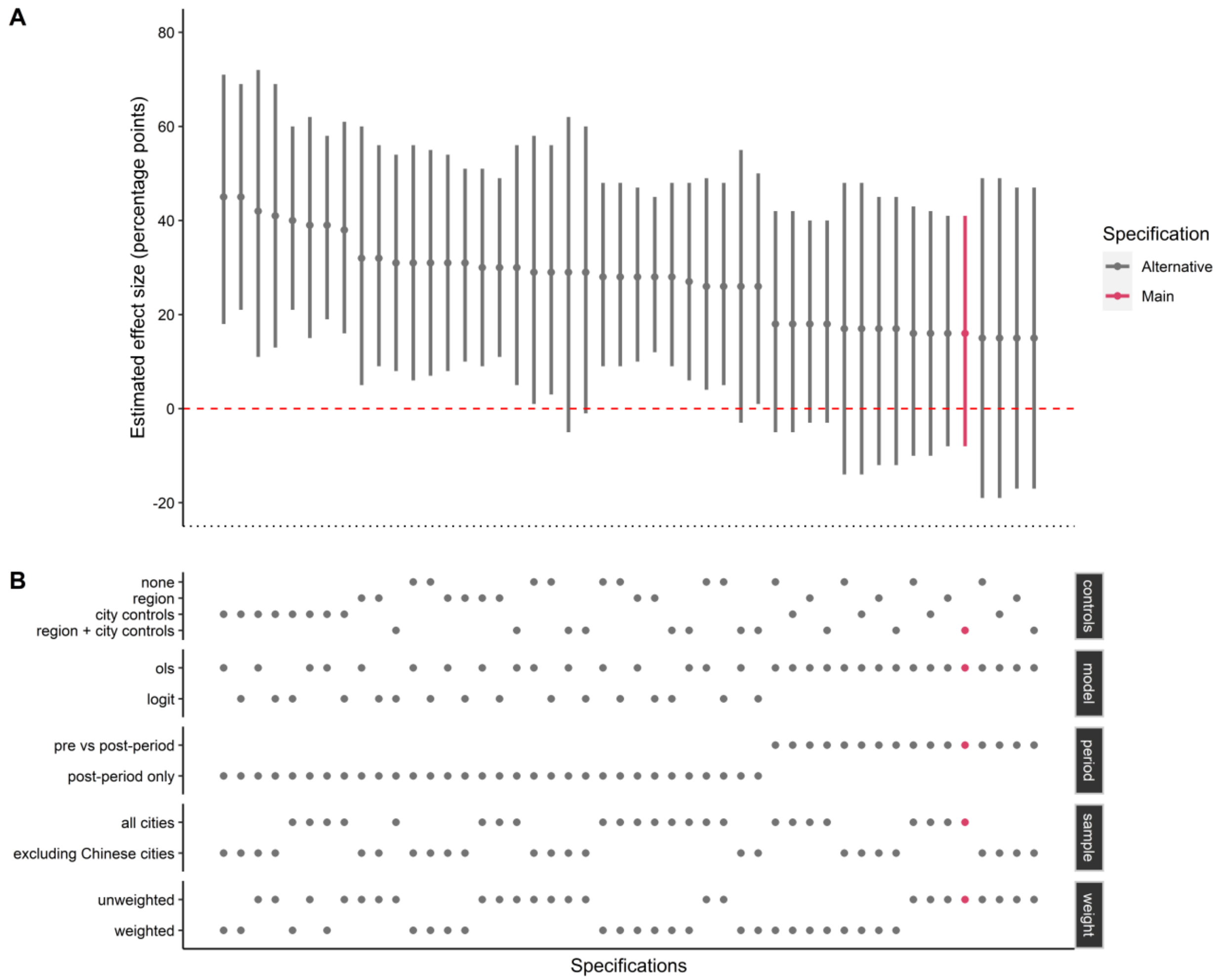
Figure A.1. GHG inventory reporting by inventory accounting framework



Source: Authors' calculations using data from C40, cCR, CDP, Nangini et al. (2019), and WRI.

Notes: Cities included represent the ITT sample. The pre-period covers CDP's 2011 to 2015 reporting years, whereas the post-period spans 2016–2019. The dotted line indicates the beginning of the post-period. In the pre-period, most of our data on Chinese cities' reporting comes from Nangini et al. (2019). We assume a 2013 reporting year for Chinese cities that are listed in Nangini et al. (2019), based on the average delay between measurement year and reporting year observed in CDP records.

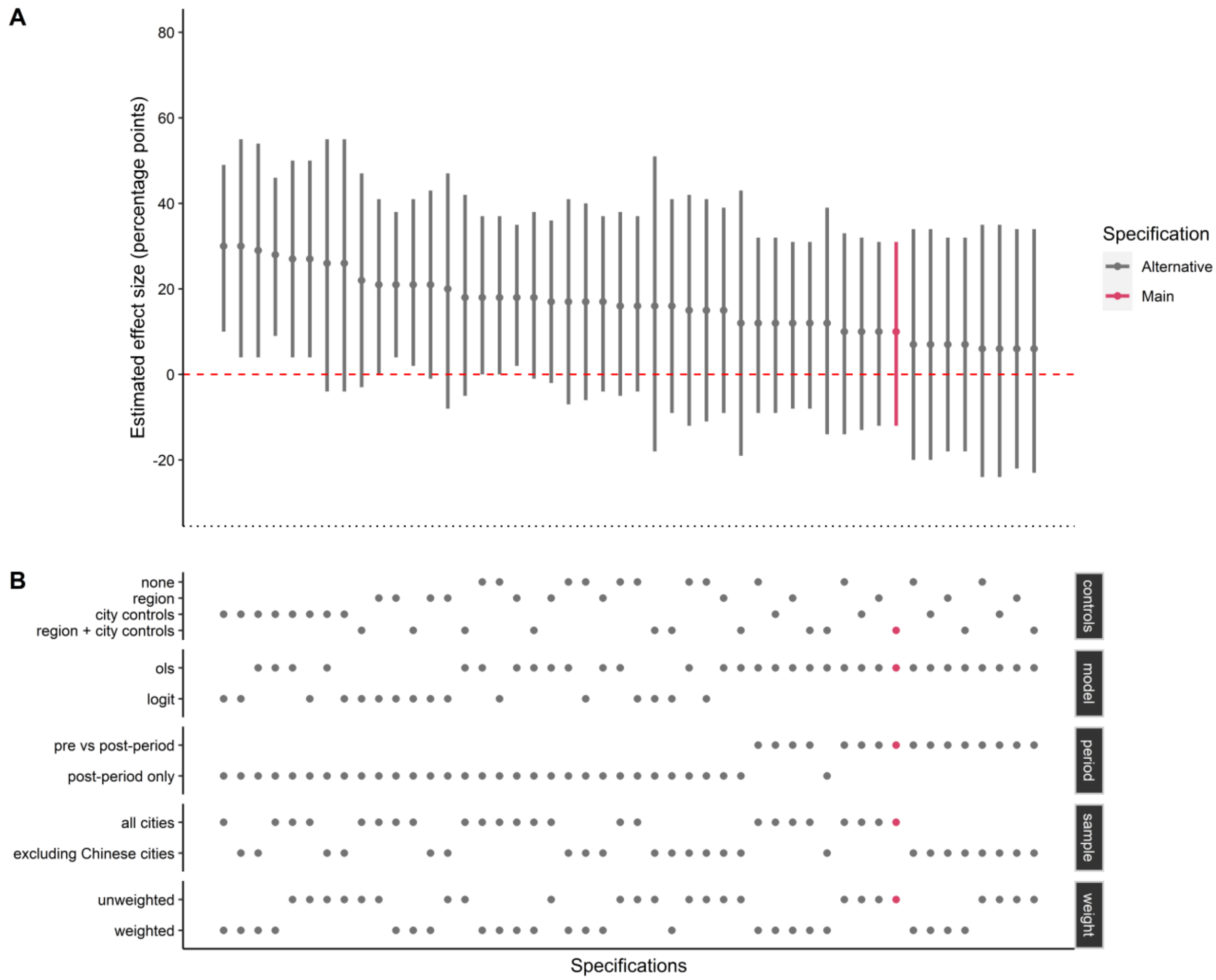
Figure A.2. Specification plot for GPC inventory reporting regressions



Source: Authors' calculations using data from C40, cCR, CDP, Kummu et al. (2019), Nangini et al. (2019), UN, and WRI.

Notes: Each specification is identified by a unique combination of model type, controls, periods, samples, and weights. In panel A, each point represents the estimate effect size for a specification type listed below. The vertical lines in panel A indicate the range of 95 percent confidence intervals across all specifications. The estimated effects in panel A align vertically with each combination of specification features, which are indicated by points in panel B. Our main specification is shaded in pink.

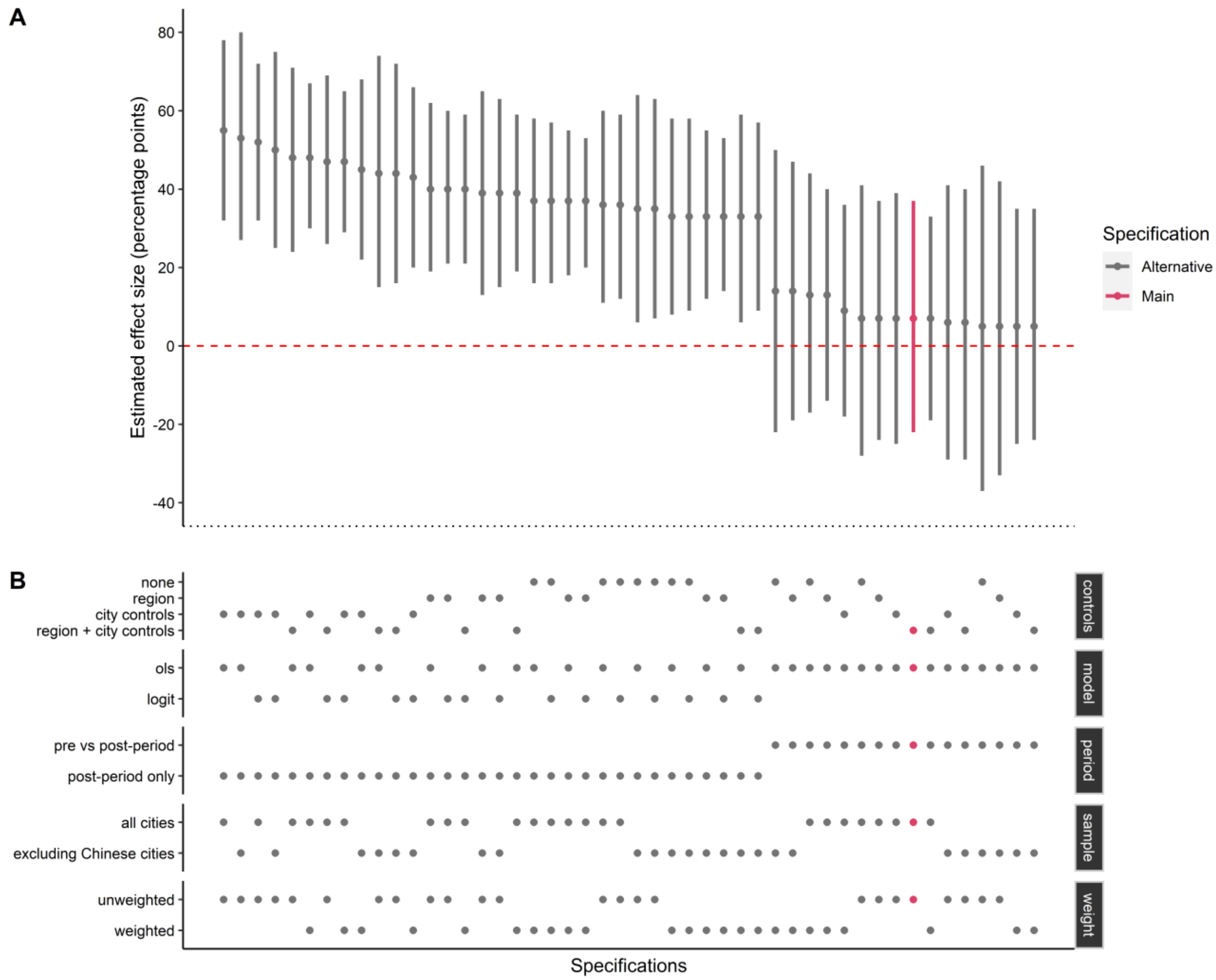
Figure A.3. Specification plot for BASIC inventory reporting regressions



Source: Authors' calculations using data from C40, cCR, CDP, Kummu et al. (2019), Nangini et al. (2019), UN, and WRI.

Notes: Each specification is identified by a unique combination of model type, controls, periods, samples, and weights. In panel A, each point represents the estimate effect size for a specification type listed below. The vertical lines in panel A indicate the range of 95 percent confidence intervals across all specifications. The estimated effects in panel A align vertically with each combination of specification features, which are indicated by points in panel B. Our main specification is shaded in pink.

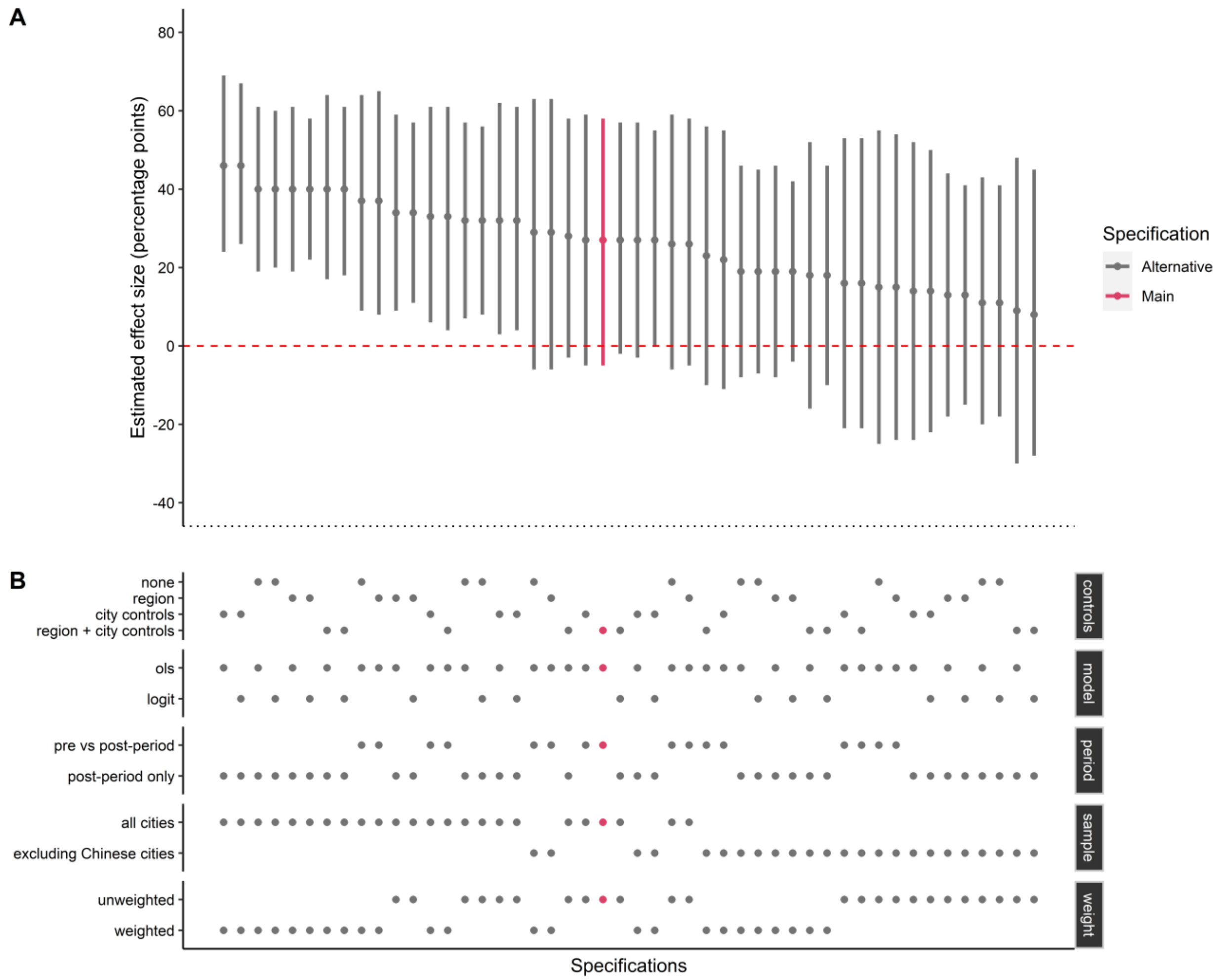
Figure A.4. Specification plot for mitigation action reporting regressions



Source: Authors' calculations using data from C40, cCR, CDP, Kummu et al. (2019), Nangini et al. (2019), UN, and WRI.

Notes: Each specification is identified by a unique combination of model type, controls, periods, samples, and weights. In panel A, each point represents the estimate effect size for a specification type listed below. The vertical lines in panel A indicate the range of 95 percent confidence intervals across all specifications. The estimated effects in panel A align vertically with each combination of specification features, which are indicated by points in panel B. Our main specification is shaded in pink.

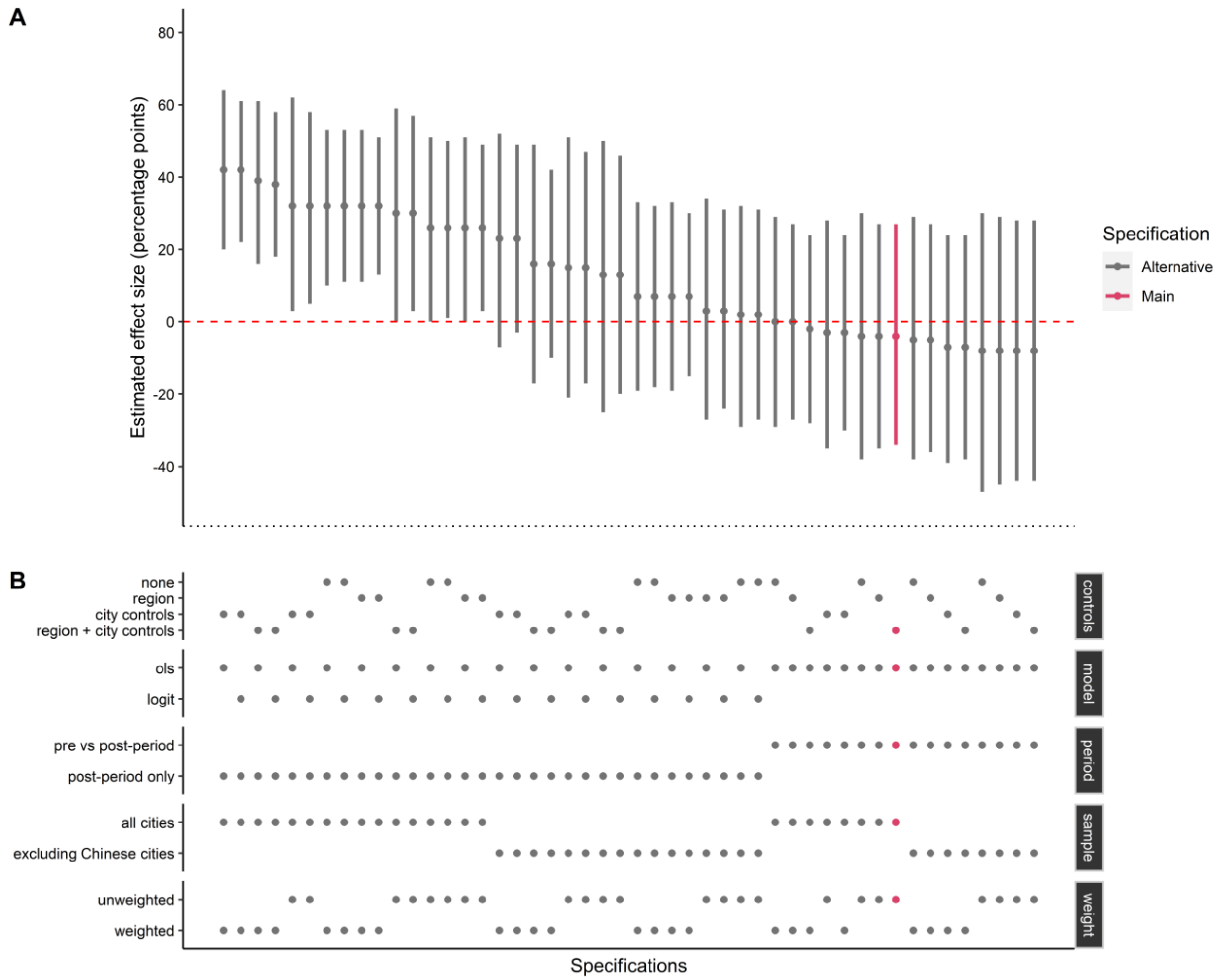
Figure A.5. Specification plot for climate action plan reporting regressions



Source: Authors' calculations using data from C40, cCR, CDP, Kummu et al. (2019), Nangini et al. (2019), UN, and WRI.

Notes: Each specification is identified by a unique combination of model type, controls, periods, samples, and weights. In panel A, each point represents the estimate effect size for a specification type listed below. The vertical lines in panel A indicate the range of 95 percent confidence intervals across all specifications. The estimated effects in panel A align vertically with each combination of specification features, which are indicated by points in panel B. Our main specification is shaded in pink.

Figure A.6. Specification plot for emissions reduction targets reporting regressions



Source: Authors' calculations using data from C40, cCR, CDP, Kummu et al. (2019), Nangini et al. (2019), UN, and WRI.

Notes: Each specification is identified by a unique combination of model type, controls, periods, samples, and weights. In panel A, each point represents the estimate effect size for a specification type listed below. The vertical lines in panel A indicate the range of 95 percent confidence intervals across all specifications. The estimated effects in panel A align vertically with each combination of specification features, which are indicated by points in panel B. Our main specification is shaded in pink.

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