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Greener city centers, grayer peripheries?

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In 2016, Paris authorities decided to completely close a section of the "Georges-Pompidou" embankment road to car traffic. This policy brief describes the effects of this decision on traffic conditions on the city's ring road. The closure of the riverside road has increased the occupancy rate, likelihood of congestion, and travel times on eastbound routes, particularly on the southern ring road. Since the ring road's surroundings are more densely populated than those near the River Seine, it is possible that this closure had a negative net effect on the number of residents exposed to more polluted air.

- The closure of the riverbank road led to a 15% increase in congestion on the west-east lanes of the southern ring road, equivalent to an additional two minutes for a 10km trip.
- Because of the higher population densities around the ring road, the resident population potentially affected by air degradation is about twice as large as the resident population that benefited from the closure.
- These short-term effects raise questions about the dependence of the Paris metropolitan area on the automobile and about the appropriate level of governance of environmental policies.

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Introduction

Faced with the challenges posed by automobile congestion and increasing air pollution, cities and metropolises often favor policies aimed at reducing or controlling road capacity, through restrictive measures on automobile use (road space rationing, route closures, car-free zones, etc.), combined with the promotion of alternatives to automobile use (development of public transport, promotion of cycling, walking, etc.). Paris is no exception and over the past 20 years has built new tramway and subway lines, developed bicycle lanes and access to self-service bicycles, and closed roads within the city center.

The implementation of these measures is regularly the subject of controversy, as the constraints on travel that they may cause lead many stakeholders to question their direct or indirect effects, whether economic, social or environmental. In particular, these policies are **suspected of displacing rather than reducing congestion and pollution** because they do not address the deep dependence of cities on private car transport. But there are few studies that document these features.[1]

In general, policies to combat urban congestion will only have a positive effect on air quality if they do not increase congestion on non-targeted roads. For example, Davis (2008) showed that traffic restrictions (notably, road space rationing) in Mexico City did not change drivers' behavior to the point of encouraging them to adopt other less polluting modes of transport. **To date, there is no evidence that these policies have improved air quality.**

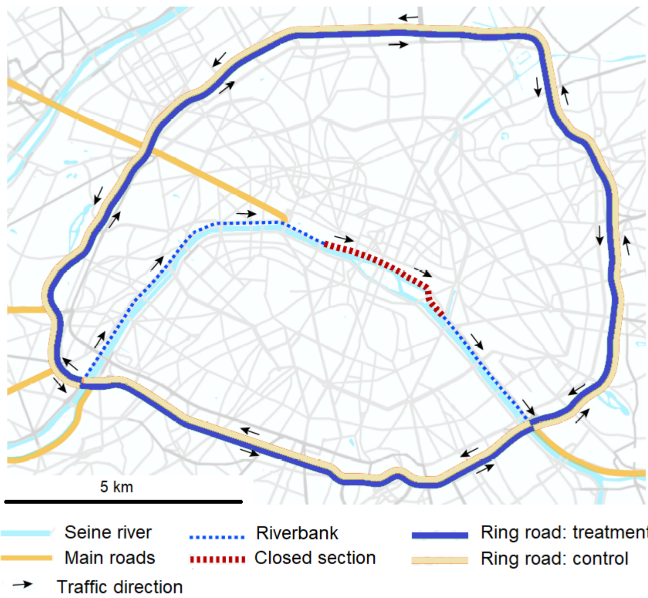
This policy brief analyzes the impact of the closure of the riverside road (Voie Georges-Pompidou, hereafter, GP), implemented in September 2016 by the Mayor of Paris, on car traffic and air quality on the outskirts of the capital.

[1]Most studies of the impact of road infrastructure provision on automobile traffic focus on the opening of new roadways (Duranton and Turner, 2011).

The closure of the Georges-Pompidou road

Since the early 2000s, Paris has implemented several policies designed to limit car traffic in the city center, including road restrictions. **The most emblematic route closure to date is the pedestrianization of a 3.3km stretch of the expressway along the right bank of the Seine, the GP, in September 2016**. The GP was the only "expressway" (i.e., without pedestrian access or intersections) through the city. As shown in Figure 1, this lane was part of a 13km route crossing Paris from southwest to southeast. The closed segment is located near Notre-Dame Cathedral, the tourist hub and physical center of the city. Until 2016, this road was used by about 40,000 vehicles per day for travel within the city but also, for suburb-to-suburb trips, as a possible substitute for the ring road.

Figure 1: Map of affected roads



Note : This figure represents a map of the main road network of Paris. The blue dotted line represents the riverbank road used by cars to cross Paris. The red dotted line corresponds to the 3.3km of the route that are now closed to car traffic. The blue solid line represents the southern outer and northern inner ring road (from west to east). The solid beige line represents the southern inner and northern outer ring road (from east to west). The main access roads to the city are shown in orange.

Every year since 2002, part of this thoroughfare had been closed between mid-July and mid-August for the "Paris beaches" event, but **on September 1, 2016, the city authorities permanently closed the section between the entrance to the tunnel under the Tuileries and the exit from the Henri IV tunnel**, citing air pollution control as the main reason.[2]

This decision was heavily criticized, in particular following the opinion issued by the environmental authority noting the inadequacies of the impact study relating to this closure project, particularly in the evaluation of delays for travel beyond the Parisian city center (DRIEE, 2016). Following these negative assessments, the Paris regional authority initiated the creation of a committee to evaluate the closure of the Parisian riverside road. A report published by this committee several months after the closure pointed out, among other things, the possible existence of traffic spillovers from the closed lane to the ring road and its approaches to the southwest, and listed the potential consequences, in terms of noise and air pollution (CRSE, 2017).

How can the effect of this closure be understood?

Existing evaluations, including the AirParif (2017) report, are based on a pre- and post-closure comparison of the situation on a number of major roads or neighborhoods. While useful, **these evaluations do not provide a causal basis for establishing the impact of the policy due to the lack of a sufficiently precise control group**.

The closure of this section of the GP may indeed have had an impact on the entire Parisian network. In addition, many urban policies were implemented or extended during the same period (bicycle plan, tramway expansion, etc.). **To establish the causal effect of this closure, we compare the changes in traffic on routes directly affected by the closure of the GP with those on routes only indirectly affected.** This empirical strategy, known as a difference-in-differences approach, uses a particular characteristic of the GP: its unidirectional flow.

Accordingly, we focus on the effect of the closure of the GP on traffic on the ring road for two reasons: first, because this high-speed road is a particularly relevant substitute for the GP, especially its southern part; second, because the architecture of this road makes it particularly plausible to compare lanes that are directly impacted, i.e., with the same direction of traffic as the GP, to lanes that are only indirectly impacted in the event of a total reduction in traffic, i.e., the lanes going in the opposite direction.

The causal effect of the closure on the displacement of road traffic is identified by comparing, before and after September 1, 2016, the ring-road lanes going in the same direction as the riverfront road (eastbound, treatment group) **with the ring-road lanes going in the opposite direction** (westbound, control group). Specifically, the treatment group corresponds to the sections, or "arcs", forming the southern outer ring road and the northern inner ring road, and the control group corresponds to the arcs forming the southern inner ring road and the northern outer ring road (see Figure 1). This strategy is based on the assumption that in the absence of the closure of the GP (i.e., if the GP had remained open), the traffic changes on the lanes of the treatment group and the control group would have been similar; therefore, any differences we observe are due to the closure of the GP.

It is important to note that our empirical difference-in-differences strategy does not, in theory, allow us to draw conclusions about all traffic. In particular, the differences we measure would be artificially magnified if car traffic declined on the control group lanes. However, average traffic remains very stable in this group, suggesting that we can interpret our results as a total effect.

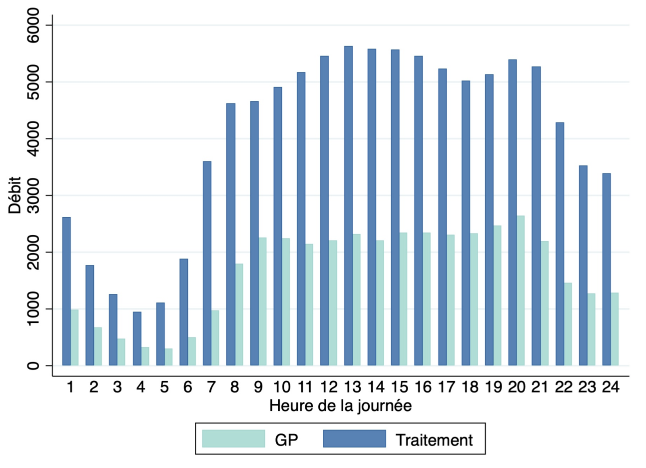
How do we measure traffic on the ring road?

We use data from the sensors of the city authorities, described in detail in Box 1. **These data provide road occupancy rate and traffic flow, at each hour of each day,** for a large number of sections that correspond to the main traffic routes. The ring road is particularly well equipped with sensors, so that traffic is measured almost exhaustively. Before the closure of the GP, the average traffic flow was 200,000 vehicles per day, almost equally divided between the treatment and control groups. Figure 2 shows that traffic on the GP represented about 40% of the traffic on the treated lanes before the closure.

We analyze the road occupancy rate directly in our study. However, a high occupancy rate is not problematic when traffic is free-flowing: Circulation only becomes inefficient when the increase in the number of vehicles on the road decreases the traffic flow. Formally, this tipping point can be measured by estimating the concave quadratic relationship between flow and occupancy rate. Beyond this point, traffic is considered to be congested. On average, the treatment lanes were congested 24% of the time before the GP closure. This proportion was as high as 39% for the treatment lanes of the southern ring road.

[2] At $60 \mu g/m^3$ in 2015, nitrogen dioxide levels measured on the Quais Célestins (just above the GP) far exceeded the European Union limit of $40 \mu g/m^3$.

Figure 2: Hourly traffic flow in 2015



Source: Road traffic data described in Box 1.
Note : The treatment group is composed of the eastbound ring roads.
Interpretation: Between 6pm and 7pm, the average flow in 2015 is 5,000 vehicles for the treatment group and almost 2,500 for the GP.

The displacement of traffic following the closure of the Georges Pompidou road

Occupancy rate and congestion increase

The effect of the closure on occupancy and the probability of congestion is summarized in Figure 3. **We observe that the closure of the GP worsened traffic on the eastbound ring road compared to the westbound ring road.** On average, occupancy increased by an additional 1 p.p., which corresponds to a 3.6 p.p. increase in the probability of congestion (or +15% compared to the year before the closure). As noted earlier, since the control group was little affected by the GP closure, this result more or less matches the total effect on the treatment lanes.

This increase is always higher on the southern ring road because it represents a more direct substitute for the GP. On the southern ring road, the effect is stable on all sections, which supports the hypothesis that the closure of the GP had a significant impact on travelers who were using it to cross the entire city. Moreover, the effect is particularly high during the day and on weekdays, suggesting that **the closure mainly affected commuters**. Finally, **the effect seems stable over time, suggesting little adaptation by users, meaning that there was little reduction in travel demand, even after three years.**[3]

Average speed decreases, and travel time increases

To translate these results into concrete terms for users, we make assumptions about the average length of vehicles (4.5 meters) that allow us to calculate an average speed per road section (see Box 1) and to give an idea of the time lost per crossing of Paris. For this exercise, we focus on the southern ring road, which is a more direct

[3] This observation is consistent with findings in the literature on new road construction that demand adjustment is typically observed after 5 to 10 years (Duranton and Turner, 2011).

Box 1: Data

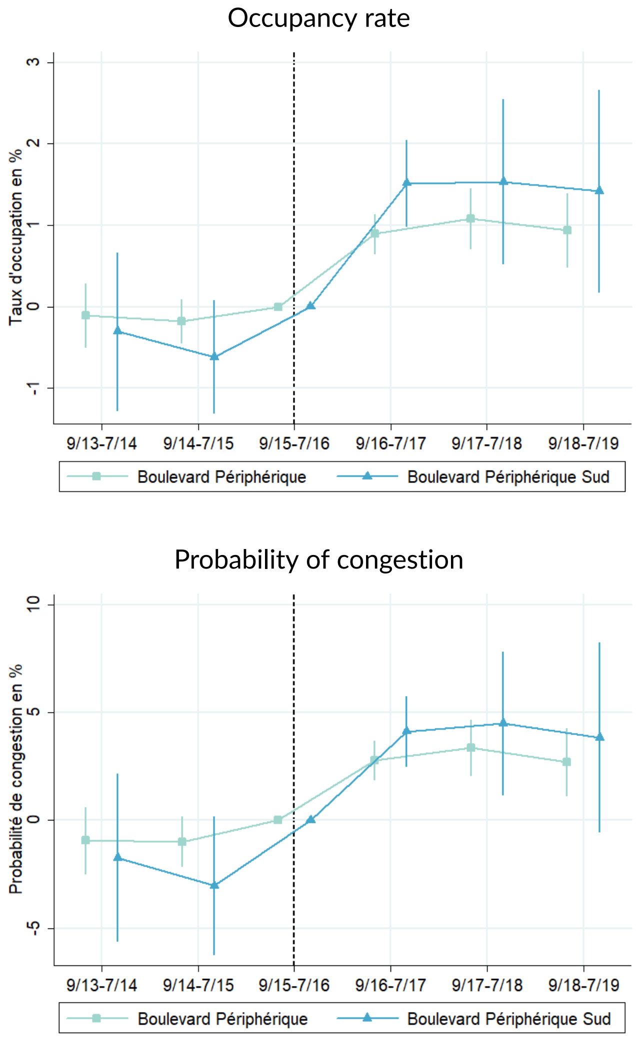
Road traffic data from permanent sensors, available at opendata.paris.fr, measure occupancy rate and traffic flow on hundreds of route sections, or arcs, for every hour of every day since 2013.

- The occupancy rate corresponds to the time vehicles are present on the section as a percentage of a fixed time interval (one hour for the data provided). Thus, a 25% occupancy rate over an hour means that vehicles were present on the section for 15 minutes. The rate provides information on traffic congestion. The sections are designed to allow the deduction, from a specific measure, of the state of the traffic on an arc.
- The traffic flow is the number of vehicles having passed the counting point during a fixed time interval (one hour for the data provided).
- The average speed V per section *i* at time *t* is calculated using the lane flow rate D_{it}, occupancy rate O_{it}, section length L_i and vehicle length ℓ with the following formula: $V_{it} = D_{it} \times (\ell + L_i)/O_{it}$.

The **pollution** data come from Airparif, an independent association, instructed by the Ministry of the Environment to implement the means of monitoring the ambient air quality in the Paris region. We use data from a station located near the ring road, east of Paris (rue Edouard Lartet), which records hourly emission levels of nitrogen dioxide and fine particles for the period 2013 to 2018.

The **population** data are taken from the 2016 population census. They use the IRIS (Îlots Regroupés pour l'Information Statistique) nomenclature, which allows a detailed analysis of population density. Each IRIS zone is composed of 1,800 to 5,000 inhabitants and is designed to ensure that the environment considered is relatively homogeneous.

Figure 3: Annual impact on traffic



Source: Road traffic data described in Box 1.
Note : Effect of GP closure on occupancy rate and probability of congestion on the eastbound ring road (treatment group), compared to the westbound ring road (control group). Vertical bars are 95% confidence intervals.
Interpretation: The differences in occupancy rate and congestion probability between the two groups increased by 1 p.p. and 3.7 p.p., respectively, in the year following the closure.

substitute for the GP, and this is confirmed by our results on the occupancy rate and congestion.

We can distinguish two groups of losers: the "direct losers", who were using the GP before September 2016 and were forced to change their route; and the "indirect losers", who were already using the southern ring road before the GP closure and are affected by the worsening traffic conditions. We restrict ourselves to the simplified case where all these users were using the two routes in their entirety.

The closure of the GP reduced average speed by 1.7 km/h on the whole sample and by 3.1 km/h on the southern ring road. In terms of lost time, we estimate that direct losers experienced a six-minute increase in travel time, while indirect losers lost two minutes.

Beyond traffic: What impact on air quality?

To translate our results on road traffic into environmental terms, we adopt a more indirect strategy. The conclusions we draw are therefore to be treated with caution, as they are based on poorer quality data and rely on a greater number of assumptions. First, we focus our analysis on pollution along the routes studied.[4]

Secondly, as we do not have pollution data at the same level of detail as we do for traffic, we proceed indirectly by relying on the extrapolation of already established results. Finally, we propose a very imperfect measure of exposure to pollution based on the estimation of the number of residents affected by a deterioration or improvement in air quality.

Measuring changes in air quality

To document the evolution of air quality around the southern ring road, we proceed in several steps. First, we use data on pollutant emissions from a fixed sensor located near the ring road (see Box 1) to study the correlation between traffic speed on the ring road and NO2 emissions recorded by this sensor.[5] This negative correlation allows us to establish that **emissions increased along the southern ring road following the closure of the GP, due to the reduction in average speed that it caused.**[6] Furthermore, the scientific literature has shown that **an increase in pollutant emissions from road traffic leads to an increase in NO2 concentration in the air in the vicinity of roads.**[7]

Due to the lack of sufficiently complete and accurate traffic speed data on the GP, we cannot adopt the same methodology for the GP and therefore use the results of the Airparif (2017) study in this case. This study, based on the operation of numerous mobile sensors that mea-

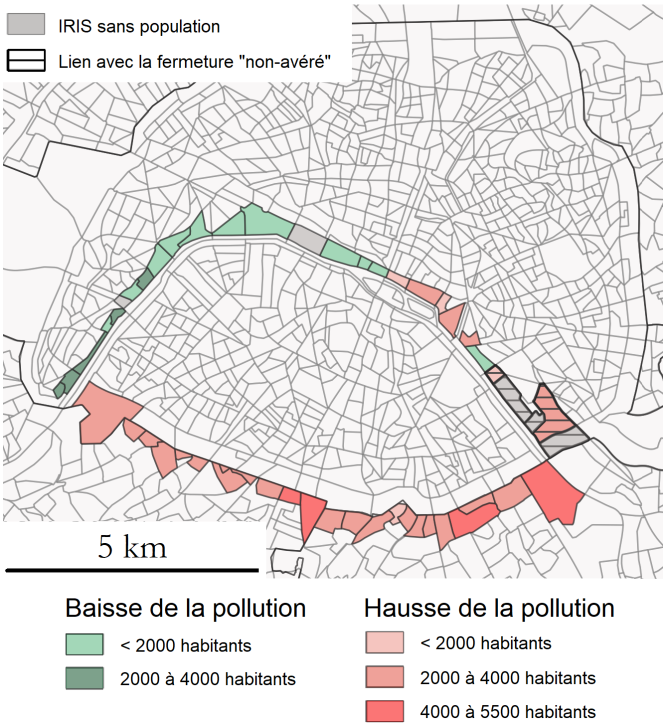
[4] The study of average pollution levels in the Paris region reveals the preponderance of road traffic, especially along major roads, in emissions of nitrogen oxides and fine particles (Airparif, 2014).

[5] We focus on NO2 because the concentration of this gas is particularly correlated with vehicle emissions (Health Effects Institute, 2010), while PM2.5 fine particulate matter is not affected by vehicle speed (Batterman et al., 2010).

[6] This negative correlation is a result previously observed in other contexts (Pandian et al., 2009).

[7] See, for example, Gilbert et al (2003) and Jerrett et al (2007). Given the lack of separate data on NO2 concentrations on the inner and outer ring road, it is difficult to provide a quantification of the effect of the closure of the GP on NO2 concentrations in the vicinity of the ring road, although it is arguable that these have probably increased.

Figure 4: Map of affected populations



Source: AirParif (2017) and pollution and population data described in Box 1.
Note : This figure represents a map of Paris neighborhoods at the IRIS level. The colored IRIS zones are located along the GP and south of the southern ring road. The population shown is from the 2016 Census. Information on pollution trends is from AirParif (2017) for the GP and our own results for the ring road. The population of the striped IRIS zones is not taken into account in our quantification.

sured local variations in pollution between 2015-2016 and 2016-2017, identifies the sections of the GP where pollution has decreased and those where it has increased. **Pollution has indeed decreased on the GP, but not everywhere**: In particular, along the pedestrianized section, the study paradoxically highlights an increase in pollution along the "*quais hauts*" (high quays) of the river. We use these results, even if, in the absence of a control group, it is difficult to attribute these changes to the closure of the GP alone.[8]

Measuring the resident population exposed to pollution

To aggregate these changes, we use a measure of pollution exposure based on the resident population along the GP and along the ring road. To do so, we use data from the 2016 Census at the granular level of the IRIS zones (see Box 1). The selected IRIS zones are depicted in Figure 4. We only retain the population residing south of the southern ring road, which is closest to the most affected route.[9] Moreover, we do not take into account the population living around the Quais de Bercy, for which the increase in pollution measured by AirParif is not, according to their results, attributable with certainty to the closure of the GP. These choices are intended to construct a "lower bound" of the resident population exposed to an increase in pollution, i.e. a measure of the minimum affected resident population.[10]

Adding up the population of all IRIS zones along the part of the GP where air quality has improved, we obtain **a maximum of 22,000 inhabitants**. Conversely, at least **7,700 people reside in the IRIS zones located around the section of the GP where pollution has increased. In the IRIS zones adjacent to the south of the southern ring road, the resident population amounts to more than 47,000 people.**

We conclude that the number of residents exposed to potential air quality degradation due to increased nitrogen dioxide is at least twice as high as the number of residents benefiting from improved air quality. This difference is due to the fact that the area immediately adjacent to the southern ring road is much more heavily populated than the area near the riverbank road.

Conclusion

This policy brief shows that the closure of the GP road significantly increased car traffic on the ring road, especially on the southern part. Combining these results with external data, we estimate that **most residents in the immediate vicinity of the affected routes were exposed to a deterioration in air quality**.

Our study has several limitations: (1) It focuses on two roads; (2) It does not take into account other benefits to users of the pedestrianized zone; and (3) It does not directly address the other stated objective of the closure, which is to encourage a modal shift from motorists to public transport.[11] Finally, (4) the study does not iden-

[8] In particular, the use of simple time differences does not allow us to take into account the downward trend in NO2 or the variations caused by other events.

[9] To assess pollution exposure, we use the fact that the highest NO2 levels are within 300-500 meters of a major road (Health Effects Institute, 2010). Some IRIS zones extend more than 300m from the road. In this case, we limit ourselves to an estimate of the number of residents within 300m based on an assumption of homogeneity of population density within the IRIS zone.

[10] In this analysis, we also ignore the pollution exposure of motorists on the road and consider only the residents in the area. However, vehicle flow on the southern outer ring road is at least twice as high as that on the GP.

[11] To study this phenomenon rigorously, individual longitudinal data on the modes of transport used and the routes taken would be needed. To our knowledge, such data do not exist.

tify long-term social and geographic effects, such as the decision to buy a new car or a reduction in commuting distances.

However, **our results also raise questions about the political and economic context of such a closure decision**, implemented by Paris authorities but negatively affecting the inhabitants of neighboring communities. What framework should be adopted to manage externalities related to road traffic, when winners and losers of the same public policy are on both sides of jurisdictional boundaries?

On the other hand, it is clear that the debate on the legitimacy of such decisions is difficult to conduct in the absence of precise quantification of the pollution. **To carry out these arbitrations and to inform political decisions and public deliberation, it is essential to collect more detailed and systematic data on air quality near major roads.**

Alternatives to simple road closures exist. Urban tolls, which can adjust in real time to the traffic situation, have been shown to be effective in some contexts (Santos et al., 2008). If it is not possible to act directly on prices, for example because of strong political constraints, other options that are more flexible in terms of time and space can also be considered to reduce the number of traffic lanes. One example is the current experiment on the inner ring road, which reserves the left lane for vehicles carrying several passengers.[12]

Reference study

This policy brief is based on the following article: "Are car-free centers detrimental to the periphery? Evidence from the pedestrianization of the Parisian riverbank", by Léa Bou Sleiman (CREST Working Paper 2021-03).

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[12] It is inspired by the "High-Occupancy Vehicle Lanes" that began to develop in the United States in the late 1970s. These policies can also be supported by differential pricing principles (Poole et al., 2000).

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