Departament d´Economia Aplicada

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Abstract

Many cities in Spain are wrapped in air containing excessive levels of particulate matter, nitrogen dioxide and ozone, generally a problem in big cities caused by traffic. Pollutants largely associated with volume of traffic in urban cities and their outlying areas, such as Madrid and Barcelona, which is suffering from one of the worst levels of air pollution in the country. According to the World Health Organization (WHO), 96.8% of Spain population breathe pollutant air. This paper shows empirical evidence about the contribution of public transport in the air quality of Barcelona using public transport strikes, through econometric analysis based on data from 2008 - 2016. During the study period, there were 147 days affected by some type of public transport strike: bus (57), metro (21), train (71) and tram (4) system, against 4 general strikes. The estimates indicate that public transit strikes have a statistically significant and positive effect on the concentration level of SO_2, CO, PM_{10} and NO_X in all over the city, especially in the case of metro and train. These results also allows us to understand better how commuters substitute transports modes between them and what policies can be implemented to increase the use of public transports.

Key words: Air pollution; Public transport strike; Econometric regression analysis; Public Transport Substitution

JEL Codes: C33 Q53 Q56 Q58

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1. Introduction

According to recent World Health Organization (WHO) reports, air pollution caused an estimated 7 million deaths globally in 2016, i.e. one in eight deaths worldwide is caused by poor air quality (WHO, 2016; WHO, 2018). In economics terms, the costs of air pollution exceed 3.7 billion euros per year, or 6.2% of the planet's wealth (Álvarez, et al., 2019). In Spain these costs represent between 1.7% and 4.7% of Spain's Gross Domestic Product (GDP), equivalent to between 413 and 1,125 euros per inhabitant per year (Ceballos, et al., 2018).

The NO_2 concentrations in air were responsible for about 8,900 premature deaths in 2015, due to the long-term exposure in Spain. These estimates are a good indication of the magnitude of the health impacts of air pollution (European Environment Agency, 2018). In this regard, the European Commission announced in July 2019 the decision to refer Spain to the European Court of Justice (CJEU) to exceed air pollutant emission legal limits – NOx in particular in the urban areas of Madrid and Barcelona (European Commission, 2019).

Every day a human being breathes approximately 14–15 m^3 of air, which contains many atmospheric and biological components including tropospheric ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matters PM, nitrogen oxide (NO), pollen, spore grains, etc. (Rahman, et al., 2019). The report of the air quality in the Spanish State, according to the values established by Directive 2008/50/EC and Royal Decree 102/2011, indicated that 31.8% of the whole population breathed polluted air, outside the legal standards during 2018 however, according with the WHO, 96.8% of Spain population breathe pollutant air (Ceballos, et al., 2018).

An effective strategy to mitigate the problem of air pollution and its severe impacts on urban areas is to get a good understanding of its causes and consequences, how the chemical composition of the atmosphere changes over time, and how pollutants affect humans, ecosystems, climate and, subsequently, society and the economy (European Environment Agency, 2018). Several scientific studies have found that exposure to polluted air increases mortality risk, cardiovascular, respiratory morbidity, and the incidence of lung cancer (Lim, et al., 2013; Raaschou-Nielsen, et al., 2013; Cohen, et al., 2018; Morellia, et al., 2019). Other studies have found that urban areas experience higher concentrations of chemical pollutants in the air than rural areas, due to increasing numbers of vehicles, reduced road capacity and few investments in public transportation (da Silva, et al., 2012; Rahman, et al., 2019). About 70% of environmental pollution in European cities come from motorized transport (Rojas-Rueda, et al., 2012).

One of the policies taken by large cities to reduce traffic-related pollution is to encourage the use of public transport rather than private. However, when public transport services are cancelled or their frequencies drastically reduced, the opposite effect could happen and cause an intensification in the number of journeys by private vehicles. The public transport strikes provide an exceptional opportunity to study the influence of traffic emissions on the air quality of urban areas (Meinardi, et al., 2008). In the course of public transport strikes, public transport services are canceled, or their periodicity drastically reduced, the traffic and congestion rise, and in the same way, the air pollution levels grow (Tsapakis, et al., 2012). The increase in private traffic flows, congestion and delays caused by public transport strikes has been evidenced in many studies, for instance, in Los Angeles the average delay on the road increases 47% when the transit service ceases due to strike action (Anderson, 2014), in Rotterdam the travel time, the car flow and the bicycle increase for public transit strikes (Adler and van Ommeren, 2016) while in some German cities the total number of car hours increase by 11 to 13% during strikes (Bauernschuster, et al., 2017).

Traffic-related air pollution is mainly due to engine exhaust, including nitrogen oxides (NO_X), volatile organic compounds (VOC), carbon monoxide (CO), carbon dioxide (CO_2), particulates (PM_{10}), sulfur dioxide (SO_2) and lead (Bauernschuster, et al., 2017). Scientists in different parts of the world have examined the impact of public transport strikes on air pollution and have found findings such as: in Athens a reduction of approximately 40% for Black Smoke (BM) during days when drivers of diesel-powered taxies and transportation buses went on strike was observed; also it was found that southern–southwestern wind flows increased PM levels and precipitation events decreased them (Chaloulakou, et al., 2005); A study in Milan showed that ozone concentrations increase by 11-33% during a public transport strike (Meinardi, et al., 2008); in São Paulo was observed increases in air pollutant concentrations (in terms of PM_{10}) during a strike day, which are also affected by rain or wind conditions (da Silva, et al., 2012); in the five largest cities of Germany it was observed that transit strikes have significant effects on air pollution. Emissions of PM_{10} increased by 14% and NO_2 concentrations increased by 4% (Bauernschuster, et al., 2017). In this study sulphur dioxide was used as a placebo, assuming that emissions of this pollutant are non-existent in modern cars as gasoline no longer contains significant amounts of sulphur. Finally, the Barcelona-wide concentrations of NO_2, NO, PM_{10} and BC were between 4% and 8% higher during public transport strikes (Basagaña, et al., 2018).

These arguments are based on the hypothesis that public transport strikes increase road-traffic related air pollution. The main aim of this case study research is to get a better knowledge and to test this hypothesis. Which is being described as an approach that focuses on understanding the Barcelona city, which is considered one of the most polluted cities in Europe and that the main source of atmospheric pollution is the motor-vehicle traffic (L'Agència de Salut Pública, 2017). The novelty of this work is to analyze air quality data monitored hourly through an econometric regression model adjusted by control variables that could affect the level of pollution, evaluating CO, SO_2, O_3, PM_{10} and NO_X concentrations, to provide a quantitative approximation of the relationship between public transport strikes and air pollutant concentration. Further, it is the first study to include an analysis of the effect of general strikes on air pollution in Barcelona. In addition, once analyzed the impact of public transportation strikes on pollution, we use these results to understand how commuters substitute between different modes of transport. That is, we want to analyze how commuters choose between different transportation modes when they cannot choose their preferred mode due to a strike. This analysis could help to understand better how commuters choose their preferred mode of transport and what their direct substitutes are. With that in mind, policy makers can improve their decisions related to public transport polices.

The research is organized as follows: Section 2 provides key information about the variables that make up the panel data used in this case study. In the Section 3, empirical strategy is described. Section 4 summarizes the results and discusses the main findings of the assessment. Section 5 concludes.

2. Data

The city of Barcelona is the second most populated urban area in Spain. Its metropolitan area is composed of 36 municipalities representing 3,247,281 inhabitants, of whom 1,620,809 live in the city of Barcelona, with a high population density of 16,000 inhabitants/km^2 in a space of 101.35 km^2. The dominant mode of transportation is carried out on public transport with 39.8% of the daily trips, followed by close for mode on foot, with 32.4%, in third place is the private vehicle by 25.6% and for last in bicycle with 2.2% (Àrea d'Ecologia, Urbanisme i Mobilitat, 2018).

The city's public transport network mainly includes a metro system, a bus network, a regional railway system (railroad lines operated by the Ferrocarrils de la Generalitat de Catalunya (FGC) and other by Rodalies RENFE.) and Tram (Table 1).

Table 1. Characteristics of the Barcelona Public Service System

System of public transport	Trips in millions/2017	Contribution (%)
Metro	390.4	40
Bus	369	37
Train RENFE	113.4	12
Train FGC	84.3	9
Tram	28	3

Source: Own elaboration according Àrea d'Ecologia, Urbanisme i Mobilitat, 2018

The data used in the analysis is a panel data composed by several variables that come from different sources. The information about the public transport strikes was compiled from the official newspaper of the government of Catalonia (Diari Oficial de la Generalitat de Catalunya, DOGC) in charge of publishing the Government's decrees and resolutions determining the minimum services to be provided in the event of a strike. For this, we used the advanced search of the DOGC website, using the thematic descriptor “garanteix el servei essencial de transport”[3] for the period from January 2008 to December 2016. (http://dogc.gencat.cat/ca/pdogc_canals_interns/pdogc_cercador_de_normativa/?destParam=cercaAdv). In order to guarantee an accurate identification of strike activity, we employed a verification procedure in the information-gathering process. Therefore, we only consider those strikes that, in addition to appearing in the DOGC, were also announced, and confirmed, in the newspaper "La Vanguardia" (https://www.lavanguardia.co/hemeroteca). The main point if this validation is due to the fact that, although some strikes were published in the DOGC, finally the trade unions cancelled them. From the files, we extracted information on the date and time of the strike, the type of transport affected (bus, metro, train RENFE, train FGC or tram), and the minimal services during the strike. In addition to the public transport strikes, the date of the general wave that affected the city of Barcelona in the same period of study was included. This data was collected from Home Office of Spanish Government. Table 2 lists the number of days and hours affected by the strike type. During the study period, there were 147 days affected by some type of public transport strike against 4 general strikes. The bus and train system (train RENFE and train FGC) registered the highest number of strike days, with 57 and 71 (51 from RENFE and 20 from FGC), respectively. Followed by metro, with 21 days, and the tram, with 4 days. There was only 6 days overlap in the strikes of the different transport system. During the study period, the years most affected by strikes in Barcelona were 2012, followed by 2016 and 2013.

Table 2. Description of Strikes (2008-2016)

Duration	**Strikes**						
	General	**All PTS***	**Bus**	**Metro**	**Train RENFE**	**Train FGC**	**Tram**
Day	4	147	57	21	51	20	4
Hour	96		449	184	597	191	76
2008	0	14	14	0	0	0	0
2009	0	6	2	0	0	0	4
2010	1	17	0	0	8	9	0

3 Guarantees the essential transport service

2011	1	10	0	0	3	7	0
2012	2	30	19	6	4	1	0
2013	0	26	9	0	17	0	0
2014	0	9	3	0	3	3	0
2015	0	12	1	0	11	0	0
2016	0	29	9	15	5	0	0

*All PTS: All Public Transport Strikes
Source: Own elaboration

The public transport system in Spain is considered an essential service for the community and a right to free circulation (Article 19 of the Constitution), therefore the interruptions of public transport must be regulated by the government entity guaranteeing the ordering of a minimum service that goes generally between 20% and 65% of the usual service.

Ambient air levels were collected from the Air Quality Monitoring web of the Government of Catalonia. We gather the hourly mean data from 5 types of pollutants, CO, SO_2, O_3, PM_{10} and NOx (this last pollutant was estimated, NOx = NO + NO_2) for 14 air quality stations located in the metropolitan area of Barcelona. Additionally, data about weather conditions is gathered from the meteorological service of the Government of Catalonia, the Meteocat. In this case, we collect the hourly average data about temperature, rain, relative humidity, atmospheric pressure and wind’s force and direction. In Fig. 1 we can see the location of the air quality stations (in yellow) and the meteorological stations (in green). As it can be seen, all the city is covered by air quality stations.

Figure 1. Location in Barcelona of the air quality and meteorological stations. Source: Own elaboration

The current WHO guideline value of 40 µg/m^3 (annual mean) was set to NO_2, 20 µg/m^3 (24-hour mean) to SO_2, 20 µg/m^3 (annual mean) to PM_{10} and 100 µg/m^3 (an 8-hour daily average) to O_3 (WHO, 2005). The city-wide average level is shown in the Table 3. When these guide values were compared with this work data, it was founded that particulate matter (28.818 µg/m^3) and nitrogen dioxide (41.126 µg/m^3) exceeded the limits, the last one caused that European Commission has decided to refer Spain to the Court of Justice of the EU over poor air quality. (European Commission, 2019).

Table 3. Descriptive statistics for the pollutants in our sample

Pollutant (unit of measure)	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
SO_2 (µg/m^3)	2.734	2.885	1	232
O_3(µg/m^3)	43.436	30.831	0	207
CO (mg/m^3)	0.429	0.297	0.1	7.1
PM_{10} (µg/m^3)	28.818	20.389	0	1484
NO (µg/m^3)	18.296	33.380	0	810
NO_2 (µg/m^3)	41.126	25.939	0	269

Source: Own elaboration

The average information of the meteorological stations of the city of Barcelona are summarized in the following table:

Table 4. Descriptive statistics for the meteorological conditions in our sample

Variable (unit of measure)	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
Temperature (°C)	16.872	6.334	-4.6	38.6
Atmospheric pressure (hPa)	1006.356	13.840	932.7	1036.7
Precipitation (mm)	0.038	0.436	0	30.2
Relative humidity (%)	65.795	15.607	4	100
Velocity of the wind (m/s)	2.333	1.578	0	16.4
Direction of the wind (°North)	203.007	96.615	0	359

Source: Own elaboration

3. Empirical Analysis

To assess the impact of the public transport strike on the different pollutants, we use the following reduced model:

$$Y_{it} = \beta_0 + \beta_i Strike_{it} + \beta_r X_{it} + \beta_j \mu_i + \varepsilon_{it}$$

Where the dependent variable Y_{it} is the hourly average of each of the pollutants (NO_X, CO, PM_{10}, SO_2 and O_3), in the air quality station i, in the hour t, which are explained by:

The main variable of interest is "Strike" that is a dummy variable that take value 1 if exists a strike during this hour "t", and zero in other case. The strike variable refers to the different types of strikes analyzed: general strike, all public transport strikes (All PTS), bus, metro, train (train RENFE and train FGC). One variable for every kind of transport mode except for the case of Tram. In this sense, tram had only 4 strikes in all the period. And the strikes were only during 2 consecutive days of 2 different weeks in 2 different years. We do not think that these low numbers of strikes being also compressed in time are enough to detect the effect of these strikes on air pollution. In addition, the results for the other transportation modes does not vary if we include these strikes.[4] Finally, we considered one general strike as a bus strike (27th January 2011) because the strike was not successful except for the case of Bus transportation where the service was reduced by 25%. As we expect that strikes increases the use of private car, our hypothesis is that the coefficient of this variable would be positive, meaning that a strike in any mode of public transportation generates an increase of pollution during the hour t. In addition we also control for a whole set of variables that could affect the level of pollution (X_{it}): 1) the day of the week, for which variable dummies are included for each one of the days of the week, except Sunday, which acts as a point of reference; 2) the month of the year, include dummy variables for each of the months, except December, which acts as a reference variable; 3) the different years, including dummy variables for each year of the sample, except 2016, which acts as a reference variable; 4) Atmospheric conditions, so we include the hourly average of temperature, atmospheric pressure, accumulated rainfall and relative humidity; 5) Wind speed; 6) the wind direction, for which we include 15 dummy variables that take value 1 when the wind has blown in that direction during that hour. The wind direction can be: North (N) North-Northeast (N-NE), North-East (NE), East (E), East-Northeast (E-NE), East-Southeast (E-SE), South-East (SE), South (S), South-Southwest (S-SW), South-West (SW), West-Southwest (W-SW), West (W), West-Northwest (W-NW), North-West (NW), North-Northwest (W-NW), and North (N). Enter all the addresses except the North (N) that is taken as a reference.

Variable μi is the fixed effect by air quality station and capture any intrinsic characteristic of their location[5]. Before carrying out the econometric estimations, it was found that the database, with a data panel structure, presented problems of heterokedasticity and autocorrelation of order one. To try to overcome autocorrelation and heteroskedasticity in the model, one of the regressions was verified by The Newey-West standard error correction. In the following section results are shown.

[4] Results from the model with Tram can be requested to authors directly.

[5] We perform a Hausmann test that confirm the preference of fixed effects over random effects.

4. Results and Discussion

The reduced results of the econometric regressions can be seen in the next table. Each cell is the coefficient (βi) obtained for each transport mode strike in the econometric regression and indicates the impact of the type of strike on the concentration of each pollutant. In the table we present only the relevant coefficient, but the complete econometric estimations are presented in Annex 1.

Table 5. Impacts of the strikes on the pollution levels

Pollutant	**Strikes**				
	General	**Bus**	**Metro**	**Train RENFE**	**Train FGC**
SO_2 ($\mu g/m^3$)	0.158 (0.143)	0.024 (0.065)	0.411*** (0.086)	-0.054 (0.056)	0.133 (0.153)
O_3 ($\mu g/m^3$)	1.233 (1.445)	0.465 (0.349)	-3.314*** (0.647)	-1.751*** (0.370)	1.530** (0.777)
CO (mg/m^3)	0.040** (0.019)	0.051*** (0.007)	0.047*** (0.011)	0.017*** (0.006)	-0.009 (0.010)
PM10 ($\mu g/m^3$)	1.430 (1.224)	0.351 (0.648)	3.577*** (0.998)	2.696*** (0.517)	-2.246** (0.907)
NO_X ($\mu g/m^3$)	-8.477*** (2.114)	0.774 (0.911)	5.450*** (1.080)	3.942*** (0.704)	-1.856 (1.271)

Standard errors in parentheses
* $p<0.05$, ** $p<0.01$, *** $p<0.001$
Source: Own elaboration by Stata

The estimates indicate that public transport strikes have a statistically significant and positive effect on the concentration level of SO_2, CO, PM_{10} and NOx, pollutants associated with car traffic, mainly due to engine exhaust gases (Bauernschuster, et al., 2017). The transport interruptions recorded during our study caused an increase in the concentration of these pollutants. This increase is associated with the rise in traffic of private vehicles in the city during a public transport strike (Tsapakis, et al., 2012; Anderson, 2014; Bauernschuster, et al., 2017). The opposite happens with the ozone level, because it generates a negative effect during the strikes of metro, train RENFE. Indicating that the concentration of O_3 decreases during these strikes. This is due to chemical reactions ($NO+O_3=NO_2+O_2$ and

$NO_2+O_3=NO+2O_2$) that convert emissions of NO and NO_2 to the atmosphere in lower levels of O_3 (Eckhardt, et al., 2013).

In general we can see how the effects of transport strikes generates an increase in the levels of pollution in the case of Metro, Train. In comparison with the average values for our period, the levels of NOx during the hours of a strike generates an increase of 9.2% in the case of Metro, and a 6.6% in the case of RENFE trains. This result is similar in the case of SO_2, CO and PM_{10}. In the case of CO the strikes of Metro increase the levels of this pollutant in 11%, Train (RENFE) strikes in 4% and Bus in 11.9%. In the case of PM10, strikes of Metro generates an increase of 12.4% over the average, Train (RENFE) in 9.4%. Like we explain previously, the evolution of O_3 is the opposite to the evolution of NOx, so we see negative impacts of Metro, and Train (RENFE) over the levels of O_3, a 7.6%, and 4.0% respectively. In the case of SO_2, the only significant strikes are the Metro ones, that generate an increase of 15%. While Bauernschuster, et al. (2017) in his study did not get statistically significant effects of traffic strikes by SO_2 pollution and argues that sulfur dioxide emissions from cars are almost non-existent, because modern gasoline no longer contains significant amounts of sulfur, it is important to note that in Barcelona until 2020 cars produced before 2000 could enter the city. So, we think that, in comparison with Bauernschuster et al. (2017), our results for SO_2 are different because the average antiquity of cars in Barcelona is higher than in their study and also due to the high percentage of old diesel cars consuming sulfur in Barcelona. In 2016, 48% of private cars used diesel as a fuel. In addition, 89% of vans and 90% of trucks used diesel as a fuel. Also, it is important to remark that on 2016, the average antiquity of private cars in Barcelona was 10.5 years and almost 47.2% of them were 11 years old or more[6]. Moreover, it is important to note that that 60% of Barcelona's bus fleet still runs on fuel, so a transfer of passengers from the subway to buses (which increase slightly their frequency) can explain this increase.

The results are not so conclusive in the case of bus and FGC Train strikes. Buses strikes have not effects over NO_X SO_2, or PM_{10}. On the other hand, they increase CO pollution (11%). FGC Train strikes presents a very similar pattern, they do not present a significative

[6] For the case of vans, the average antiquity is 11.6 years old and 39.9% of them are 11 years old or more. For trucks, the average antiquity is 13.2 years old and 61% of them are 11 years old or more.

effect on NO_X, SO_2, and CO. They present a decrease of PM_{10} pollution (but only significant at 5%) and an increase of O_3 pollution (but only significant at 5%).

In general terms, these results coincide with those obtained by Basagaña et al (2018), since they show a greater impact from the metro and train strikes. However, our results unlike those obtained by Basagaña et al (2018), show a positive impact on a greater number of contaminants. The use of hourly data for all the air quality stations located in Barcelona, together with the control of meteorological variables, can explain this greater precision in our estimates.

These results allow us to better understand what the preferred modes of transportation for different commuters are. From our results we can infer that a substantial part of commuters using metro as a first option to travel inside the city, substitute this mode of transportation by private cars. This result is explained by the fact that during metro strikes pollution increases. It is important to remark that during these strikes, the frequency of other modes of transportation is slightly increased (or not increased) so, the increase of pollution is mainly due to an increase of the use of private vehicles and also due to the roads being more congested. These results may show that users of metro usually travel long distances making it difficult to substitute these travels by foot or bicycle. Another reason behind these results is that commuters using metro travel between destinations that are not well covered with other modes of public transportation or, if they exist, are not as fast as metro discouraging its use during metro strikes.

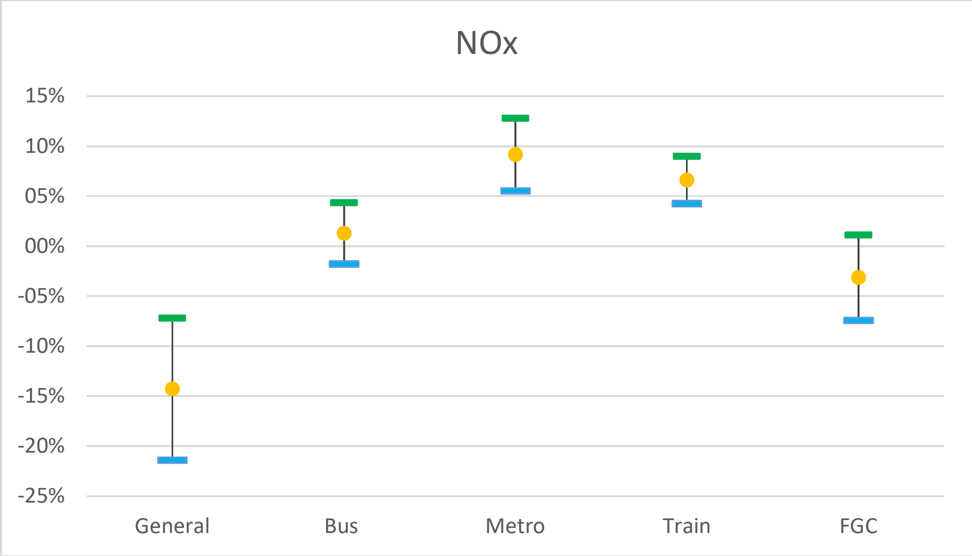
Results for RENFE are similar to those explained by metro strikes, commuters using RENFE trains tend to substitute this mode of transport by private vehicles when there are strikes. In this regard, this result may be explained by the fact that commuters travelling by RENFE usually use this mode of transportation to travel from outside Barcelona to Barcelona or vice versa, from Barcelona to outside Barcelona, with very few options for substituting RENFE trains by other public transportation modes, due to not having coaches to get into Barcelona, or, when this option exists, the frequency is very low or the duration of the travel is too long due to a high number of stops. In addition, as results show, the increase of pollution derived from RENFE strikes is lower than the one derived from metro strikes, possibly because the number of users of RENFE is lower than metro users, so the increase of public vehicles used during a RENFE strike is lower in comparison when metro is on a strike.

On the contrary, results for bus strikes are mixed, although the sign for all pollutants is positive, only is significant for O_3 and CO. In this regard, although bus has the second highest number of public transportation users, when in strike there are some effects that go in opposite directions. First, on a bus strike there are less (or no) frequency, so there is lower number of buses riding the city so pollution should decrease, on the other hand, as users cannot go by bus they may switch to private cars and pollution should increase. Depending on the magnitude of these two effects, pollution should decrease, or increase. As results show, pollution is not affected by bus strikes, but, as bus has the second highest number of public transportation users, we can infer that only a fraction of these users switch to private cars, so the two effects compensate each other. What we infer from these results is that the majority of bus' commuters switch to non-pollutant modes. That is, metro, bicycle or by foot. This result may be explained by the fact that bus travels could be shorter than metro or RENFE ones and they can be substituted easily by foot or bicycle. For the longer ones, users can substitute bus travels by metro without increasing too much the time spent.

In addition, these results are logical since the transport modes which strikes generate a greater effect on pollution are those that do not use internal combustion engines and that however can be replaced by consumers through private vehicles or the use of other public transport more polluting. In addition, metro is the public transport that move a greater volume of passengers. However, the number of passengers on FGC trains is very small, and in the case of buses, passengers can substitute this type of public transport for another such as the metro, which is in fact less polluting.

The results obtained by the general strikes are contrary to the effect caused by public transport strikes in terms of NO_X. General strikes decrease NO_X by 7.7% over the average. This happens considering that during a general strike activity are paralyzed throughout the city throughout the day, with greater restrictions on the use of private cars. However, SO_2 is 13% higher than the average, CO increases 10.4% over the average, and the effect is not significant for O_3 and PM_{10}.

You can see all this information in the next figure.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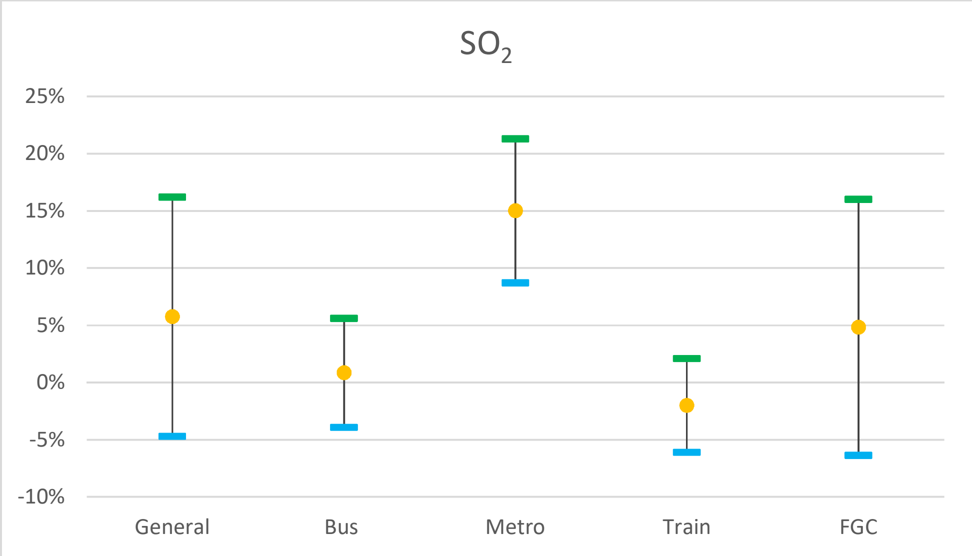
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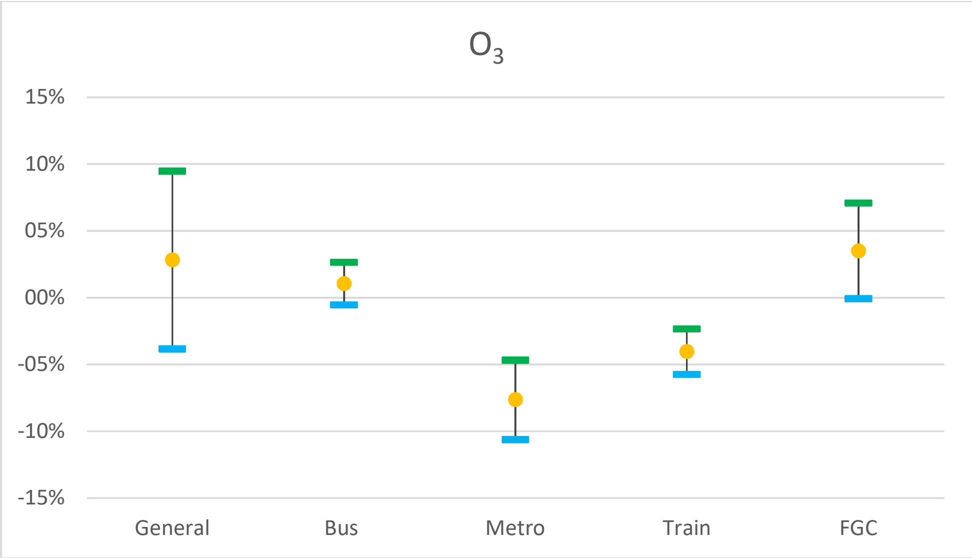

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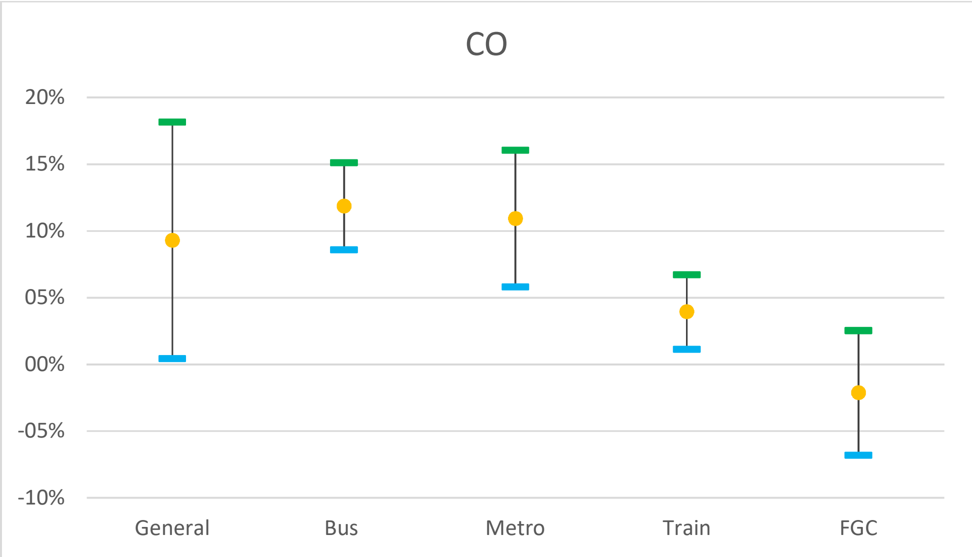

CO
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General
Bus
Metro
Train
FGC

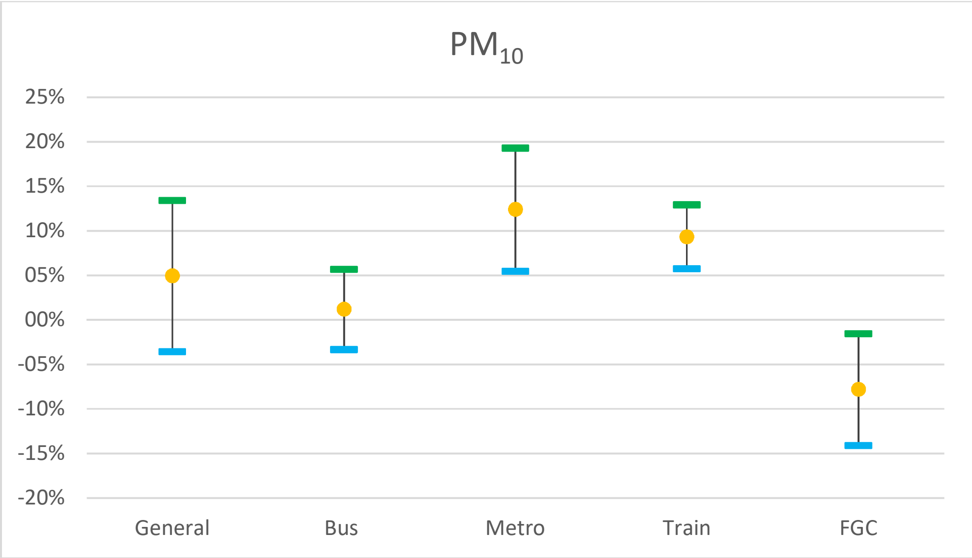

Figure ~~13~~. Percent change in concentrations of air pollutants (95% confidence intervals). Source: Own created

These estimated values correspond only to the hours in which there was a strike, without considering the impact it may generate during the hours in which no strike was called that same day. Therefore, the estimated effects are for hours where there was an effective strike, although it is possible that calls for partial strikes could generate some kind of significant effect on the hours of that same day where there was no strike. This is due to the fact that it is very probable that some public transport users, faced with the possibility of an unusual or inefficient operation (lower frequency, greater influx of passengers, etc.) of the service, will opt for private transport even though their journeys are outside strike hours. In this case, the effect of public transport strikes on pollution would be even greater.

5. Conclusion

Barcelona has one of the highest levels of air pollution in Europe, caused principally by traffic of private vehicles. In this regard, Spain has been referred to the European Court of Justice (CJEU) for exceeding air pollutant limits – mainly for NO_X in Madrid and Barcelona.

The main objective of this paper is to analyze the impact of public transport strikes on air quality in the city, through an econometric model, using a set of hourly data from 2008 to

2016. Our results shows that public transportation strikes have a significant effect on the concentration level of CO, SO_2, PM_{10} and NO_X all over the city increasing pollution. Our results show that the increase in pollution occurs when there is a strike on metro or RENFE (trains) service. On the contrary, we have not found effects over pollution for bus or FGC (trains) strikes. While evaluating another factor "general strikes", it is observed that the negative effects to air quality are found in terms of NO_X. In this sense, the results prove that the public transport system of Barcelona an option to reduce pollutant emissions. So we can infer that with more and better public transport, pollution levels would be lower.

In addition, our results can help to know how commuters from different transportation modes substitute their preferred transportation mode when there is a strike. That is, we can infer how each mode of transport is substituted by. In this regard, the majority of commuters using metro or RENFE prefer to use private cars when there is a strike on these modes. On the contrary, when there are bus strikes, commuters substitute this transportation mode by pollutants modes, like private cars but also with no pollutant ones like bicycle, metro or by foot.

These results can help policy makers to improve the public transportation of urban areas in order to cope with pollution generated by traffic. First of all, in order to avoid an increase use of private cars during metro or RENFE strikes, policy makers should redesign the other transportation modes routes to be able to complement these two transportation methods and absorb commuters from them. In addition, our results show that the higher the number of users of public transportation methods, in general, the lower the air pollution in the city is due to a reduction in the number of private cars. Increasing the number of alternatives for metro and RENFE trains would result in an increase of population using public transportation reducing pollution. Another recommendation for policy makers should be to increase the frequency, when possible, of these two transportation methods to increase their usage, mainly for the case of RENFE, as metro is the most public transport used with a high frequency. A high frequency would provoke an increase of users and a reduction of pollution.

For the case of the bus transportation, our results confirm that bus strikes do not affect air quality through the city. In this case there are some important policy recommendations. First, as some papers show, an efficient bus fleet network can reduce air pollution (Perdiguero and Sanz (2020), Jimenez and Roman (2016)), in this sense the City Council and TMB have started implementing this policy from some years ago, we recommend not only to redesign the bus fleet network for the city of Barcelona but also for the neighboring cities and also for the bus fleet doing intercity routes. This policy would reduce pollution due to an efficient network and also increase users of intercity buses reducing the number of private cars entering the city. In addition, policy makers should modernize the bus fleet in order to increase the use of non-pollutant fuels, like electric vehicles to reduce pollution from buses. In this regard, the substitution of buses using pollutant fuels by non-pollutant ones would reduce air pollution.

Acknowledgements

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Annex 1

Table A1. Effects of all public transport strike in the NO_X levels

Regression with Newey-West standard errors   Number of obs = 846085
maximum lag : 1   F(87,845996) = 2125.56
Prob > F = 0.0000

NOX	Coef.	Newey-West Std.Err.	t	P>t	[95%Conf.	Interval]
Metro	5.450	1.080	5.050	0.000	3.334	7.566
RENFE	3.942	0.704	5.600	0.000	2.561	5.322
FGC	-1.856	1.271	-1.460	0.144	-4.346	0.635
General	-8.477	2.114	-4.010	0.000	-12.620	-4.334
Bus	0.774	0.911	0.850	0.396	-1.012	2.561
Badalona	3.073	0.485	6.330	0.000	2.122	4.023
Balldovina	0.468	0.474	0.990	0.323	-0.460	1.397
Parc Ciutadella	-4.313	0.490	-8.810	0.000	-5.273	-3.353
Eixample	36.874	0.549	67.190	0.000	35.799	37.950
Hospitalet	-2.815	0.502	-5.610	0.000	-3.799	-1.832
Vall d'Hebron	34.125	0.695	49.100	0.000	32.763	35.487
Palau Reial	-9.311	0.500	-18.620	0.000	-10.291	-8.331
Poblenou	0.328	0.484	0.680	0.498	-0.620	1.276
Prat_Sagnier	2.432	0.617	3.940	0.000	1.222	3.641
Sant Adrià	12.776	0.500	25.540	0.000	11.796	13.757
Sant Feliu	-25.515	0.490	-52.050	0.000	-26.475	-24.554
Sant Gervasi	27.523	0.515	53.480	0.000	26.514	28.531
Sants	-6.130	0.488	-12.560	0.000	-7.086	-5.173
2008	198.305	20.116	9.860	0.000	158.879	237.732
2009	180.851	17.586	10.280	0.000	146.384	215.318
2010	159.819	15.061	10.610	0.000	130.300	189.338
2011	132.048	12.543	10.530	0.000	107.464	156.631
2012	109.184	10.039	10.880	0.000	89.508	128.861
2013	81.630	7.524	10.850	0.000	66.884	96.376
2014	56.863	5.031	11.300	0.000	47.003	66.723
2015	32.254	2.519	12.800	0.000	27.317	37.192
January	16.687	2.316	7.210	0.000	12.148	21.226
February	12.033	2.120	5.680	0.000	7.879	16.188
March	0.137	1.917	0.070	0.943	-3.620	3.894
April	-13.212	1.712	-7.720	0.000	-16.568	-9.855
May	-22.760	1.519	-14.990	0.000	-25.737	-19.783
June	-30.928	1.345	-23.000	0.000	-33.563	-28.293
July	-40.048	1.163	-34.450	0.000	-42.327	-37.769
August	-48.132	0.980	-49.130	0.000	-50.052	-46.212
September	-38.910	0.787	-49.440	0.000	-40.453	-37.368
October	-20.204	0.618	-32.670	0.000	-21.416	-18.992
November	-6.923	0.476	-14.540	0.000	-7.856	-5.990
h1	-5.292	0.233	-22.670	0.000	-5.749	-4.834
h2	-10.156	0.300	-33.830	0.000	-10.745	-9.568
h3	-13.183	0.293	-44.950	0.000	-13.758	-12.608
h4	-14.979	0.288	-51.980	0.000	-15.544	-14.414

h5	-11.253	0.286	-39.370	0.000	-11.813	-10.693
h6	1.536	0.295	5.200	0.000	0.957	2.115
h7	27.041	0.349	77.480	0.000	26.357	27.725
h8	43.716	0.415	105.320	0.000	42.902	44.530
h9	35.628	0.407	87.440	0.000	34.829	36.426
h10	20.552	0.364	56.420	0.000	19.838	21.266
h11	10.388	0.339	30.640	0.000	9.724	11.052
h12	4.322	0.334	12.950	0.000	3.668	4.976
h13	-0.066	0.329	-0.200	0.841	-0.712	0.580
h14	-3.811	0.326	-11.710	0.000	-4.449	-3.173
h15	-5.144	0.323	-15.910	0.000	-5.777	-4.510
h16	-2.861	0.322	-8.880	0.000	-3.492	-2.230
h17	2.100	0.322	6.520	0.000	1.469	2.731
h18	8.673	0.335	25.920	0.000	8.017	9.329
h19	14.360	0.351	40.890	0.000	13.672	15.048
h20	17.672	0.356	49.640	0.000	16.974	18.370
h21	16.682	0.356	46.880	0.000	15.985	17.380
h22	11.644	0.346	33.660	0.000	10.966	12.322
h23	5.497	0.256	21.450	0.000	4.995	6.000
Monday	18.948	0.212	89.550	0.000	18.534	19.363
Tuesday	23.509	0.220	106.750	0.000	23.077	23.940
Wednesday	26.045	0.224	116.260	0.000	25.606	26.484
Thursday	26.146	0.219	119.250	0.000	25.716	26.576
Friday	25.509	0.216	118.220	0.000	25.086	25.932
Saturday	9.776	0.191	51.090	0.000	9.401	10.151
time	0.002	0.000	6.160	0.000	0.001	0.002
timesq	0.000	0.000	13.160	0.000	0.000	0.000
t	0.755	0.024	31.310	0.000	0.708	0.803
hr	0.110	0.005	22.130	0.000	0.101	0.120
p	0.794	0.011	72.040	0.000	0.773	0.816
ppt	0.031	0.097	0.320	0.749	-0.160	0.222
v	-9.424	0.044	-214.760	0.000	-9.510	-9.338
NNE	0.795	0.437	1.820	0.069	-0.062	1.653
NE	0.925	0.428	2.160	0.031	0.086	1.764
ENE	-6.888	0.423	-16.280	0.000	-7.718	-6.059
E	-6.295	0.434	-14.510	0.000	-7.145	-5.444
ESE	-7.961	0.449	-17.710	0.000	-8.842	-7.080
SE	0.159	0.463	0.340	0.731	-0.749	1.067
SSE	5.003	0.450	11.120	0.000	4.121	5.885
S	4.100	0.454	9.040	0.000	3.211	4.990
SSW	3.795	0.433	8.750	0.000	2.945	4.644
SW	3.861	0.417	9.270	0.000	3.045	4.678
WSW	6.540	0.419	15.620	0.000	5.720	7.361
W	6.672	0.406	16.420	0.000	5.876	7.468
WNW	8.529	0.386	22.090	0.000	7.772	9.286
NW	3.229	0.396	8.160	0.000	2.453	4.004
NNW	-0.244	0.457	-0.530	0.593	-1.141	0.652
_cons	-952.559	24.680	-38.600	0.000	-1000.93	-904.188

Table A2. Effects of all public transport strike in the SO_2 levels

Regression with Newey-West standard errors
maximum lag : 1

Number of obs = 531663
F(87,531574) = 283.76
Prob > F = 0.0000

SO2	Coef.	Newey-West Std.Err.	t	P>t	[95%Conf.	Interval]
Metro	0.411	0.086	4.810	0.000	0.243	0.578
RENFE	-0.054	0.056	-0.960	0.337	-0.164	0.056
FGC	0.133	0.153	0.870	0.384	-0.167	0.434
General	0.158	0.143	1.100	0.270	-0.122	0.438
Bus	0.024	0.065	0.380	0.707	-0.103	0.152
Badalona	-0.678	0.032	-21.180	0.000	-0.741	-0.615
Balldovina	-1.318	0.039	-33.830	0.000	-1.395	-1.242
Parc Ciutadella	-0.601	0.057	-10.590	0.000	-0.712	-0.489
Eixample	-0.803	0.034	-23.680	0.000	-0.870	-0.737
Hospitalet	-0.310	0.050	-6.180	0.000	-0.408	-0.212
Vall d'Hebron	0.386	0.046	8.460	0.000	0.297	0.475
Palau Reial	-1.215	0.031	-38.770	0.000	-1.276	-1.153
Poblenou	-0.709	0.043	-16.540	0.000	-0.793	-0.625
Prat_Sagnier	-0.214	0.033	-6.440	0.000	-0.279	-0.149
Sant Adrià	-0.439	0.035	-12.580	0.000	-0.507	-0.371
Sant Feliu	-0.600	0.032	-18.630	0.000	-0.663	-0.537
Sant Gervasi	-0.986	0.033	-29.520	0.000	-1.052	-0.921
Sants	-1.087	0.041	-26.680	0.000	-1.166	-1.007
2008	7.910	1.737	4.550	0.000	4.505	11.314
2009	7.386	1.519	4.860	0.000	4.408	10.363
2010	6.764	1.304	5.190	0.000	4.209	9.319
2011	6.791	1.089	6.240	0.000	4.658	8.925
2012	5.303	0.871	6.090	0.000	3.596	7.011
2013	4.290	0.654	6.560	0.000	3.008	5.572
2014	3.176	0.437	7.270	0.000	2.319	4.032
2015	1.713	0.219	7.830	0.000	1.284	2.142
January	1.071	0.201	5.340	0.000	0.678	1.464
February	1.032	0.184	5.610	0.000	0.672	1.393
March	0.667	0.165	4.050	0.000	0.344	0.990
April	0.391	0.147	2.660	0.008	0.103	0.679
May	0.187	0.126	1.490	0.137	-0.059	0.434
June	-0.231	0.115	-2.000	0.045	-0.457	-0.005
July	-1.165	0.093	-12.600	0.000	-1.347	-0.984
August	-1.289	0.078	-16.550	0.000	-1.441	-1.136
September	-1.074	0.061	-17.740	0.000	-1.193	-0.956
October	-0.712	0.043	-16.490	0.000	-0.797	-0.627
November	-0.128	0.030	-4.310	0.000	-0.186	-0.070
h1	-0.093	0.017	-5.370	0.000	-0.127	-0.059
h2	-0.135	0.022	-6.170	0.000	-0.177	-0.092
h3	-0.156	0.021	-7.300	0.000	-0.198	-0.114
h4	-0.178	0.021	-8.420	0.000	-0.220	-0.137
h5	-0.132	0.021	-6.240	0.000	-0.174	-0.091
h6	0.028	0.022	1.300	0.195	-0.014	0.071
h7	0.405	0.024	17.140	0.000	0.359	0.451
h8	0.737	0.026	28.850	0.000	0.687	0.787

h9	0.693	0.026	26.200	0.000	0.641	0.744
h10	0.490	0.028	17.600	0.000	0.435	0.544
h11	0.355	0.029	12.380	0.000	0.299	0.411
h12	0.282	0.030	9.560	0.000	0.225	0.340
h13	0.250	0.031	7.990	0.000	0.189	0.312
h14	0.163	0.033	4.990	0.000	0.099	0.227
h15	0.021	0.030	0.710	0.480	-0.037	0.079
h16	-0.050	0.029	-1.760	0.079	-0.106	0.006
h17	-0.012	0.028	-0.420	0.671	-0.067	0.043
h18	0.102	0.028	3.640	0.000	0.047	0.156
h19	0.221	0.027	8.150	0.000	0.168	0.274
h20	0.308	0.027	11.580	0.000	0.256	0.360
h21	0.245	0.025	9.630	0.000	0.195	0.294
h22	0.131	0.024	5.450	0.000	0.084	0.179
h23	0.076	0.019	3.960	0.000	0.039	0.114
Monday	0.231	0.019	11.980	0.000	0.193	0.268
Tuesday	0.266	0.019	14.060	0.000	0.229	0.303
Wednesday	0.324	0.019	16.830	0.000	0.286	0.362
Thursday	0.337	0.019	17.470	0.000	0.299	0.374
Friday	0.400	0.021	19.280	0.000	0.359	0.441
Saturday	0.031	0.018	1.690	0.092	-0.005	0.067
time	0.000	0.000	0.650	0.518	-0.000	0.000
timesq	0.000	0.000	24.620	0.000	0.000	0.000
t	0.074	0.002	33.840	0.000	0.070	0.078
hr	-0.011	0.000	-25.620	0.000	-0.011	-0.010
p	0.026	0.001	35.440	0.000	0.025	0.028
ppt	0.016	0.008	2.100	0.035	0.001	0.032
v	-0.155	0.003	-52.390	0.000	-0.160	-0.149
NNE	-0.072	0.025	-2.880	0.004	-0.121	-0.023
NE	-0.021	0.025	-0.850	0.393	-0.070	0.027
ENE	-0.015	0.026	-0.580	0.559	-0.067	0.036
E	0.047	0.026	1.790	0.074	-0.005	0.098
ESE	0.373	0.030	12.280	0.000	0.314	0.433
SE	0.977	0.035	27.570	0.000	0.907	1.046
SSE	1.435	0.036	39.730	0.000	1.364	1.505
S	0.947	0.035	26.860	0.000	0.877	1.016
SSW	0.604	0.031	19.420	0.000	0.543	0.665
SW	0.638	0.031	20.830	0.000	0.578	0.698
WSW	0.386	0.026	14.770	0.000	0.335	0.437
W	0.280	0.024	11.530	0.000	0.232	0.327
WNW	0.280	0.023	12.460	0.000	0.236	0.325
NW	0.289	0.023	12.610	0.000	0.244	0.334
NNW	0.042	0.025	1.690	0.092	-0.007	0.092
_cons	-31.676	2.086	-15.180	0.000	-35.765	-27.587

Table A3. Effects of all public transport strike in the O_3 levels

Regression with Newey-West standard errors Number of obs = 575389
maximum lag : 1 F(84,575303) = 6914.55
Prob > F = 0.0000

O3	Coef.	Newey-West Std.Err.	t	P>t	[95%Conf.	Interval]
Metro	-3.314	0.647	-5.120	0.000	-4.583	-2.046
RENFE	-1.751	0.370	-4.730	0.000	-2.476	-1.025
FGC	1.530	0.777	1.970	0.049	0.007	3.053
General	1.233	1.445	0.850	0.393	-1.599	4.065
Bus	0.465	0.349	1.330	0.183	-0.219	1.148
Badalona	4.608	0.243	18.960	0.000	4.131	5.084
Balldovina	-2.180	0.286	-7.630	0.000	-2.740	-1.620
Parc Ciutadella	-0.345	0.245	-1.410	0.159	-0.824	0.135
Eixample	-7.542	0.244	-30.960	0.000	-8.020	-7.065
Hospitalet	5.264	0.293	17.950	0.000	4.689	5.839
Vall d'Hebron	-7.192	0.339	-21.200	0.000	-7.857	-6.527
Palau Reial	11.405	0.251	45.460	0.000	10.913	11.897
Poblenou	-1.472	0.286	-5.140	0.000	-2.032	-0.911
Prat_Jardins de la Pau		0		(omitted)		
Sant Adrià	-0.870	0.245	-3.550	0.000	-1.350	-0.390
Sant Feliu		0		(omitted)		
Sant Gervasi	-3.234	0.243	-13.310	0.000	-3.711	-2.758
Sants		0		(omitted)		
2008	-85.874	11.686	-7.350	0.000	-108.778	-62.970
2009	-77.724	10.228	-7.600	0.000	-97.770	-57.677
2010	-66.848	8.774	-7.620	0.000	-84.045	-49.651
2011	-62.105	7.319	-8.490	0.000	-76.450	-47.759
2012	-51.567	5.861	-8.800	0.000	-63.054	-40.080
2013	-38.366	4.400	-8.720	0.000	-46.991	-29.742
2014	-28.747	2.943	-9.770	0.000	-34.514	-22.979
2015	-14.938	1.478	-10.110	0.000	-17.835	-12.041
January	-6.307	1.345	-4.690	0.000	-8.942	-3.671
February	1.750	1.230	1.420	0.155	-0.660	4.160
March	12.570	1.112	11.300	0.000	10.390	14.750
April	20.736	0.993	20.870	0.000	18.789	22.684
May	21.940	0.871	25.180	0.000	20.232	23.648
June	21.077	0.766	27.530	0.000	19.576	22.578
July	20.980	0.653	32.140	0.000	19.701	22.260
August	21.160	0.545	38.840	0.000	20.092	22.228
September	18.945	0.427	44.400	0.000	18.108	19.781
October	6.523	0.301	21.650	0.000	5.933	7.114
November	0.717	0.191	3.760	0.000	0.344	1.091
h1	-0.020	0.149	-0.140	0.891	-0.312	0.271
h2	0.146	0.195	0.750	0.453	-0.236	0.529
h3	-0.443	0.195	-2.270	0.023	-0.826	-0.060
h4	-1.293	0.196	-6.600	0.000	-1.677	-0.908
h5	-4.169	0.195	-21.410	0.000	-4.551	-3.787
h6	-9.544	0.190	-50.320	0.000	-9.916	-9.173
h7	-15.127	0.182	-83.030	0.000	-15.484	-14.770

h8	-14.891	0.177	-84.070	0.000	-15.238	-14.544
h9	-9.967	0.178	-55.960	0.000	-10.316	-9.618
h10	-3.818	0.181	-21.040	0.000	-4.174	-3.463
h11	1.480	0.185	8.010	0.000	1.118	1.842
h12	6.088	0.190	32.040	0.000	5.716	6.461
h13	9.775	0.195	50.190	0.000	9.393	10.156
h14	12.713	0.198	64.160	0.000	12.325	13.101
h15	13.575	0.200	67.990	0.000	13.184	13.967
h16	12.054	0.200	60.220	0.000	11.662	12.446
h17	9.146	0.199	45.930	0.000	8.756	9.537
h18	6.427	0.195	32.950	0.000	6.045	6.810
h19	3.758	0.191	19.620	0.000	3.383	4.133
h20	1.295	0.188	6.890	0.000	0.927	1.664
h21	0.091	0.187	0.490	0.626	-0.275	0.457
h22	0.051	0.188	0.270	0.784	-0.317	0.420
h23	0.235	0.149	1.580	0.115	-0.057	0.526
Monday	-7.882	0.130	-60.650	0.000	-8.136	-7.627
Tuesday	-8.920	0.129	-68.940	0.000	-9.173	-8.666
Wednesday	-9.154	0.130	-70.610	0.000	-9.408	-8.900
Thursday	-9.419	0.130	-72.400	0.000	-9.674	-9.164
Friday	-9.532	0.130	-73.550	0.000	-9.786	-9.278
Saturday	-3.554	0.129	-27.480	0.000	-3.807	-3.300
time	-0.000	0.000	-2.430	0.015	-0.001	-0.000
timesq	-0.000	0.000	-31.140	0.000	-0.000	-0.000
t	0.554	0.014	40.650	0.000	0.527	0.580
hr	-0.204	0.003	-75.440	0.000	-0.210	-0.199
p	-0.279	0.005	-54.920	0.000	-0.289	-0.269
ppt	0.466	0.072	6.450	0.000	0.324	0.607
v	5.029	0.024	206.850	0.000	4.982	5.077
NNE	0.092	0.226	0.410	0.684	-0.351	0.535
NE	2.827	0.220	12.860	0.000	2.396	3.258
ENE	11.386	0.221	51.500	0.000	10.953	11.820
E	11.779	0.218	54.040	0.000	11.352	12.206
ESE	14.708	0.233	63.030	0.000	14.251	15.166
SE	9.862	0.234	42.100	0.000	9.403	10.322
SSE	6.573	0.230	28.640	0.000	6.123	7.023
S	4.410	0.230	19.200	0.000	3.959	4.860
SSW	3.421	0.219	15.630	0.000	2.992	3.850
SW	0.101	0.207	0.490	0.624	-0.304	0.507
WSW	-3.956	0.201	-19.710	0.000	-4.349	-3.562
W	-6.345	0.195	-32.580	0.000	-6.727	-5.963
WNW	-10.071	0.190	-52.960	0.000	-10.444	-9.698
NW	-5.714	0.197	-29.040	0.000	-6.099	-5.328
NNW	-2.382	0.225	-10.560	0.000	-2.824	-1.940
_cons	391.239	13.954	28.040	0.000	363.889	418.589

Table A4. Effects of all public transport strike in the CO levels

Regression with Newey-West standard errors Number of obs = 456725
maximum lag : 1 F(85,456638) = 761.97
Prob > F = 0.0000

		Newey-West				
CO	Coef.	Std.Err.	t	P>t	[95%Conf.	Interval]
Metro	0.047	0.011	4.130	0.000	0.024	0.069
RENFE	0.017	0.006	2.820	0.005	0.005	0.028
FGC	-0.009	0.010	-0.920	0.359	-0.028	0.010
General	0.040	0.019	2.090	0.037	0.002	0.078
Bus	0.051	0.007	7.230	0.000	0.037	0.064
Badalona	-0.073	0.003	-23.450	0.000	-0.079	-0.067
Balldovina	0.023	0.003	6.750	0.000	0.017	0.030
Parc Ciutadella	-0.065	0.004	-17.840	0.000	-0.073	-0.058
Eixample	0.254	0.003	83.650	0.000	0.248	0.260
Hospitalet	0.017	0.004	4.520	0.000	0.009	0.024
Vall d'Hebron	0.084	0.005	18.630	0.000	0.075	0.093
Palau Reial	-0.036	0.003	-13.560	0.000	-0.042	-0.031
Poblenou	-0.039	0.004	-11.110	0.000	-0.046	-0.032
Sant Adrià	0.011	0.004	3.040	0.002	0.004	0.018
Sant Gervasi	0.120	0.003	39.580	0.000	0.114	0.126
Sants	-0.083	0.003	-24.310	0.000	-0.089	-0.076
2008	0.749	0.167	4.490	0.000	0.422	1.075
2009	0.700	0.146	4.800	0.000	0.414	0.986
2010	0.623	0.125	4.980	0.000	0.377	0.868
2011	0.530	0.104	5.080	0.000	0.325	0.734
2012	0.400	0.084	4.780	0.000	0.236	0.564
2013	0.294	0.063	4.700	0.000	0.172	0.417
2014	0.152	0.042	3.620	0.000	0.070	0.234
2015	0.131	0.021	6.190	0.000	0.090	0.173
January	0.068	0.019	3.540	0.000	0.030	0.106
February	0.039	0.018	2.220	0.026	0.005	0.074
March	0.018	0.016	1.140	0.256	-0.013	0.050
April	-0.050	0.014	-3.470	0.001	-0.078	-0.022
May	-0.092	0.013	-7.270	0.000	-0.117	-0.067
June	-0.136	0.011	-12.100	0.000	-0.159	-0.114
July	-0.152	0.010	-15.580	0.000	-0.172	-0.133
August	-0.188	0.008	-22.910	0.000	-0.204	-0.172
September	-0.138	0.007	-20.970	0.000	-0.151	-0.125
October	-0.074	0.005	-14.170	0.000	-0.084	-0.063
November	-0.016	0.004	-4.190	0.000	-0.024	-0.009
h1	-0.036	0.002	-19.410	0.000	-0.040	-0.033
h2	-0.061	0.002	-25.410	0.000	-0.066	-0.056
h3	-0.074	0.002	-31.280	0.000	-0.079	-0.070
h4	-0.086	0.002	-36.780	0.000	-0.090	-0.081

h5	-0.080	0.002	-34.460	0.000	-0.084	-0.075
h6	-0.043	0.002	-18.580	0.000	-0.048	-0.039
h7	0.055	0.003	21.120	0.000	0.050	0.060
h8	0.159	0.003	48.950	0.000	0.153	0.166
h9	0.131	0.003	41.510	0.000	0.125	0.138
h10	0.040	0.003	15.030	0.000	0.035	0.046
h11	0.008	0.003	3.230	0.001	0.003	0.013
h12	0.001	0.003	0.350	0.724	-0.004	0.006
h13	0.014	0.003	5.040	0.000	0.008	0.019
h14	0.026	0.003	9.240	0.000	0.020	0.031
h15	-0.000	0.003	-0.070	0.945	-0.005	0.005
h16	-0.001	0.003	-0.320	0.745	-0.006	0.004
h17	0.016	0.003	6.270	0.000	0.011	0.022
h18	0.063	0.003	22.950	0.000	0.058	0.068
h19	0.110	0.003	37.240	0.000	0.104	0.116
h20	0.133	0.003	43.590	0.000	0.127	0.139
h21	0.117	0.003	38.890	0.000	0.111	0.123
h22	0.067	0.003	23.740	0.000	0.062	0.073
h23	0.027	0.002	12.980	0.000	0.023	0.031
Monday	0.080	0.002	43.490	0.000	0.076	0.084
Tuesday	0.091	0.002	48.170	0.000	0.087	0.094
Wednesday	0.100	0.002	52.570	0.000	0.096	0.103
Thursday	0.099	0.002	53.310	0.000	0.095	0.102
Friday	0.088	0.002	48.910	0.000	0.084	0.091
Saturday	0.026	0.002	16.130	0.000	0.023	0.029
time	0.000	0.000	4.080	0.000	0.000	0.000
timesq	0.000	0.000	1.010	0.311	-0.000	0.000
t	0.002	0.000	11.660	0.000	0.002	0.003
hr	0.001	0.000	28.660	0.000	0.001	0.001
p	0.003	0.000	36.830	0.000	0.003	0.003
ppt	-0.008	0.001	-11.080	0.000	-0.010	-0.007
v	-0.025	0.000	-84.710	0.000	-0.026	-0.025
NNE	0.008	0.003	2.520	0.012	0.002	0.014
NE	0.005	0.003	1.730	0.084	-0.001	0.012
ENE	0.008	0.003	2.270	0.023	0.001	0.014
E	0.023	0.003	6.890	0.000	0.017	0.030
ESE	0.022	0.004	6.240	0.000	0.015	0.029
SE	0.044	0.004	12.410	0.000	0.037	0.051
SSE	0.054	0.004	15.060	0.000	0.047	0.060
S	0.049	0.004	13.380	0.000	0.042	0.056
SSW	0.039	0.003	11.700	0.000	0.033	0.046
SW	0.020	0.003	6.390	0.000	0.014	0.026
WSW	0.026	0.003	8.290	0.000	0.020	0.032
W	0.022	0.003	7.290	0.000	0.016	0.028
WNW	0.022	0.003	7.610	0.000	0.016	0.027
NW	0.007	0.003	2.300	0.021	0.001	0.012
NNW	-0.002	0.003	-0.650	0.516	-0.009	0.004
_cons	-3.576	0.200	-17.850	0.000	-3.969	-3.184

Table A7. Effects of all public transport strike in the PM_{10} levels

Regression with Newey-West standard errors
maximum lag : 1

Number of obs = 242530
F(81,242447) = 419.68
Prob > F = 0.0000

PM10	Coef.	Newey-West Std.Err.	t	P>t	[95%Conf.	Interval]
Metro	3.577	0.998	3.580	0.000	1.621	5.534
RENFE	2.696	0.517	5.210	0.000	1.682	3.709
FGC	-2.246	0.907	-2.480	0.013	-4.024	-0.468
General	1.430	1.224	1.170	0.243	-0.969	3.829
Bus	0.351	0.648	0.540	0.587	-0.918	1.621
Eixample	-15.602	0.408	-38.260	0.000	-16.401	-14.802
Hospitalet	-14.182	0.380	-37.320	0.000	-14.927	-13.438
Palau Reial	-18.214	0.383	-47.540	0.000	-18.965	-17.463
Poblenou	-17.725	0.422	-41.970	0.000	-18.553	-16.898
Sant Adrià	-13.754	0.392	-35.100	0.000	-14.522	-12.985
Sant Gervasi	-15.583	0.417	-37.380	0.000	-16.401	-14.766
Sants	5.910	0.640	9.230	0.000	4.656	7.165
2008	230.805	15.838	14.570	0.000	199.763	261.847
2009	202.758	13.892	14.600	0.000	175.531	229.985
2010	176.349	11.887	14.840	0.000	153.052	199.647
2011	142.674	9.953	14.330	0.000	123.167	162.181
2012	115.898	7.980	14.520	0.000	100.257	131.538
2013	83.830	5.985	14.010	0.000	72.099	95.561
2014	56.457	4.026	14.020	0.000	48.567	64.347
2015	30.768	1.994	15.430	0.000	26.859	34.677
January	25.850	1.842	14.040	0.000	22.240	29.459
February	26.433	1.711	15.450	0.000	23.080	29.786
March	20.874	1.537	13.580	0.000	17.860	23.887
April	12.494	1.365	9.150	0.000	9.819	15.169
May	6.714	1.199	5.600	0.000	4.365	9.063
June	0.874	1.138	0.770	0.443	-1.357	3.104
July	-6.197	0.904	-6.860	0.000	-7.969	-4.425
August	-11.582	0.753	-15.370	0.000	-13.059	-10.105
September	-10.780	0.589	-18.300	0.000	-11.935	-9.626
October	-4.780	0.444	-10.760	0.000	-5.651	-3.909
November	-0.097	0.308	-0.320	0.753	-0.701	0.507
h1	-1.555	0.245	-6.360	0.000	-2.034	-1.076
h2	-2.979	0.277	-10.740	0.000	-3.523	-2.435
h3	-3.599	0.277	-13.010	0.000	-4.141	-3.056
h4	-4.095	0.267	-15.340	0.000	-4.619	-3.572
h5	-3.611	0.268	-13.470	0.000	-4.136	-3.086
h6	-1.727	0.270	-6.390	0.000	-2.257	-1.197
h7	2.752	0.279	9.860	0.000	2.205	3.299
h8	7.862	0.296	26.570	0.000	7.282	8.441
h9	9.395	0.341	27.570	0.000	8.727	10.063
h10	6.067	0.313	19.390	0.000	5.454	6.680
h11	4.470	0.315	14.170	0.000	3.852	5.088
h12	2.583	0.326	7.910	0.000	1.943	3.223
h13	0.908	0.326	2.790	0.005	0.269	1.547
h14	-0.995	0.324	-3.070	0.002	-1.630	-0.360

h15	-1.643	0.321	-5.120	0.000	-2.272	-1.014
h16	-1.022	0.317	-3.220	0.001	-1.644	-0.400
h17	0.956	0.323	2.960	0.003	0.322	1.589
h18	2.727	0.335	8.130	0.000	2.069	3.384
h19	2.873	0.308	9.330	0.000	2.270	3.476
h20	4.374	0.314	13.930	0.000	3.759	4.990
h21	4.607	0.310	14.840	0.000	3.999	5.216
h22	2.878	0.302	9.520	0.000	2.285	3.470
h23	1.234	0.247	5.000	0.000	0.750	1.718
Monday	3.578	0.179	19.970	0.000	3.227	3.929
Tuesday	5.444	0.180	30.280	0.000	5.092	5.797
Wednesday	6.367	0.176	36.280	0.000	6.023	6.711
Thursday	6.245	0.172	36.350	0.000	5.909	6.582
Friday	6.310	0.178	35.390	0.000	5.961	6.660
Saturday	2.107	0.161	13.080	0.000	1.791	2.423
time	0.003	0.000	14.130	0.000	0.003	0.004
timesq	-0.000	0.000	-0.520	0.600	-0.000	0.000
t	1.640	0.020	80.180	0.000	1.600	1.680
hr	0.131	0.004	35.200	0.000	0.124	0.138
p	0.343	0.008	44.440	0.000	0.328	0.358
ppt	-0.947	0.085	-11.210	0.000	-1.113	-0.782
v	-0.752	0.042	-17.930	0.000	-0.835	-0.670
NNE	-0.174	0.274	-0.640	0.525	-0.712	0.363
NE	0.277	0.308	0.900	0.369	-0.327	0.880
ENE	0.692	0.298	2.320	0.020	0.109	1.276
E	1.235	0.284	4.340	0.000	0.678	1.792
ESE	-0.219	0.295	-0.740	0.458	-0.798	0.359
SE	1.164	0.296	3.940	0.000	0.584	1.743
SSE	2.297	0.291	7.880	0.000	1.726	2.868
S	1.608	0.296	5.440	0.000	1.029	2.187
SSW	1.666	0.293	5.690	0.000	1.093	2.240
SW	3.403	0.285	11.930	0.000	2.844	3.962
WSW	2.245	0.262	8.580	0.000	1.732	2.758
W	0.637	0.245	2.600	0.009	0.157	1.116
WNW	1.924	0.237	8.120	0.000	1.460	2.388
NW	-0.450	0.247	-1.820	0.068	-0.933	0.033
NNW	-0.328	0.272	-1.200	0.228	-0.861	0.205
_cons	-590.908	19.311	-30.600	0.000	-628.758	-553.058

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