How much does freight transport pollute? Insights from the COVID lockdown in Paris

(Work in very progress - please do not quote)

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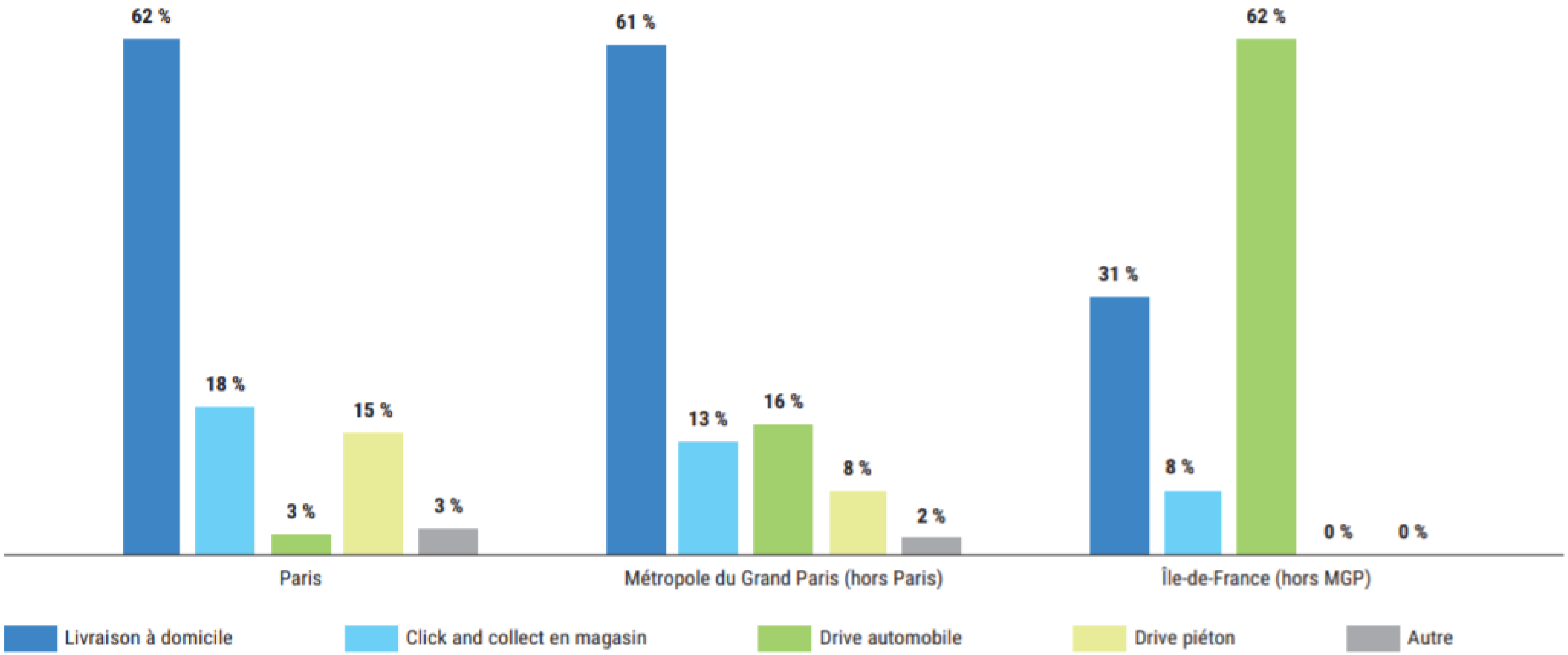
Direct consequences of the Covid lockdown in Paris

Indirect consequences (1)

Pollution : 2 300 décès évités grâce au confinement du printemps

Indirect consequences (2)

MODES DE LIVRAISON UTILISÉS PENDANT LE CONFINEMENT PAR LES CONSOMMATEURS AYANT RÉPONDU À L'ENQUÊTE



Source : Questionnaire « grand public » Apur, mai 2020

Note de lecture : Réponse à la question « Quelle(s) option(s) utilisez-vous ? » des personnes ayant déclaré avoir fait des courses alimentaires sur internet pendant le confinement.

Goals of the study

- Propose one original approach to evaluate air pollution associated with freight transport in Paris, using traffic and air pollution data as well as the first COVID lockdown (March 16th → May 11th) as an exogenous shock

- Forthcoming: question the health impacts of a “less than normal” reduction in freight flows during the COVID lockdown

Current literature

Prevailing methods to evaluate freight transport pollution:

- Coupling of freight demand-road traffic-emissions models
- Exhaust emissions measurements

Shortcomings:

- Not often based on the observation of actual freight flows
- In order to move from emissions to concentrations, one needs to also account for cofactors (weather, industry, …)

Studies that look at the health benefits of the lockdown (due to reduced pollutions) do not differentiate the respective influences of the different sources

Plan

1) Data
2) Empirical strategy
3) Econometric results
4) Contribution of freight transport to pollutants’ concentrations
5) Discussions and further research

Data

For Paris *intramuros*, between January 2018 and September 2020:

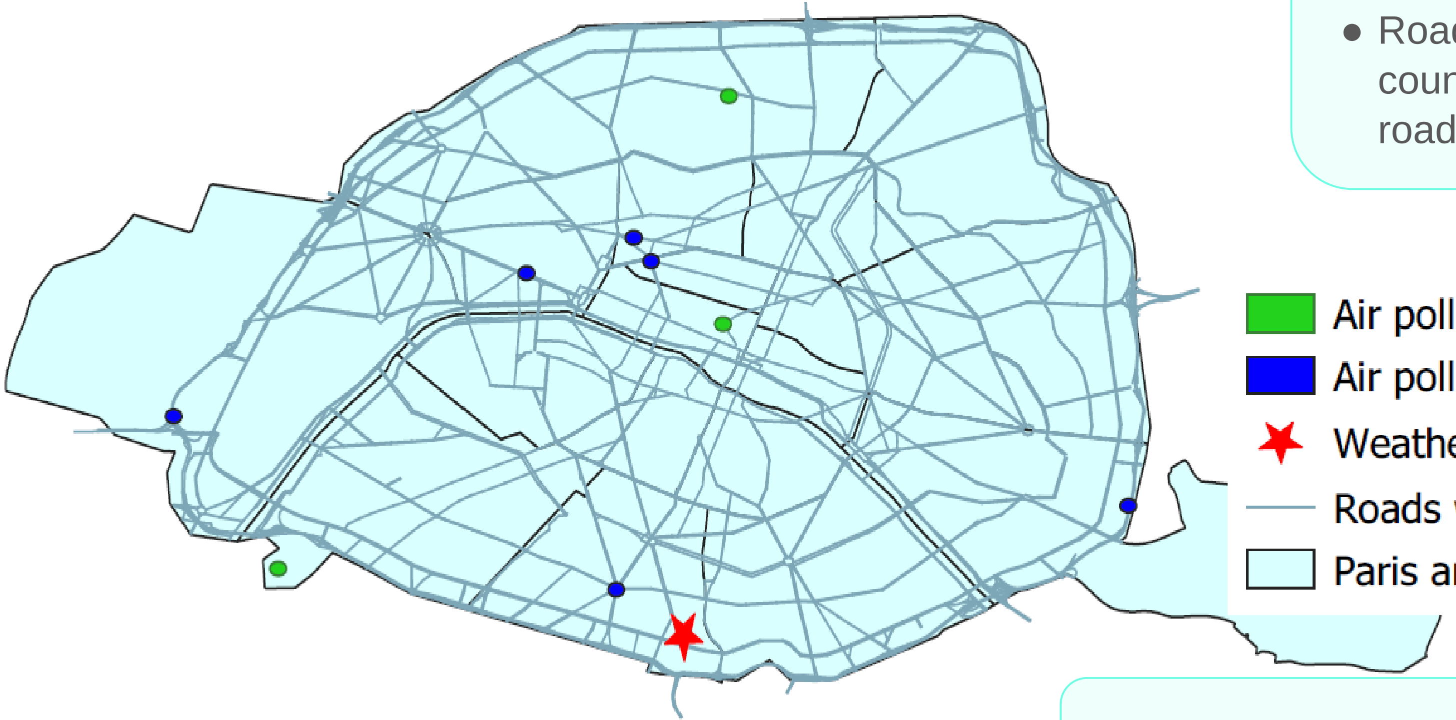
- Hourly aggregate traffic counter (traffic flow and loop’s occupancy rates)
- Hourly air pollution (concentration of NO_2, PM_{10}, NOx in µg/m3)
- Hourly weather information (temperature, wind speed…)
- Hourly electricity consumption (but for the whole Paris metropole, in MW)

Also, qualitative data regarding the drop in freight vehicles during the first COVID lockdown (carriers’ survey made by Chaire City Logistics) as well as emission factors from COPCETE

Data collection sites

In Paris:

- 6,290 roads: 1,700 km
- Roads covered by traffic counters: 598 km (4,400 road segments)



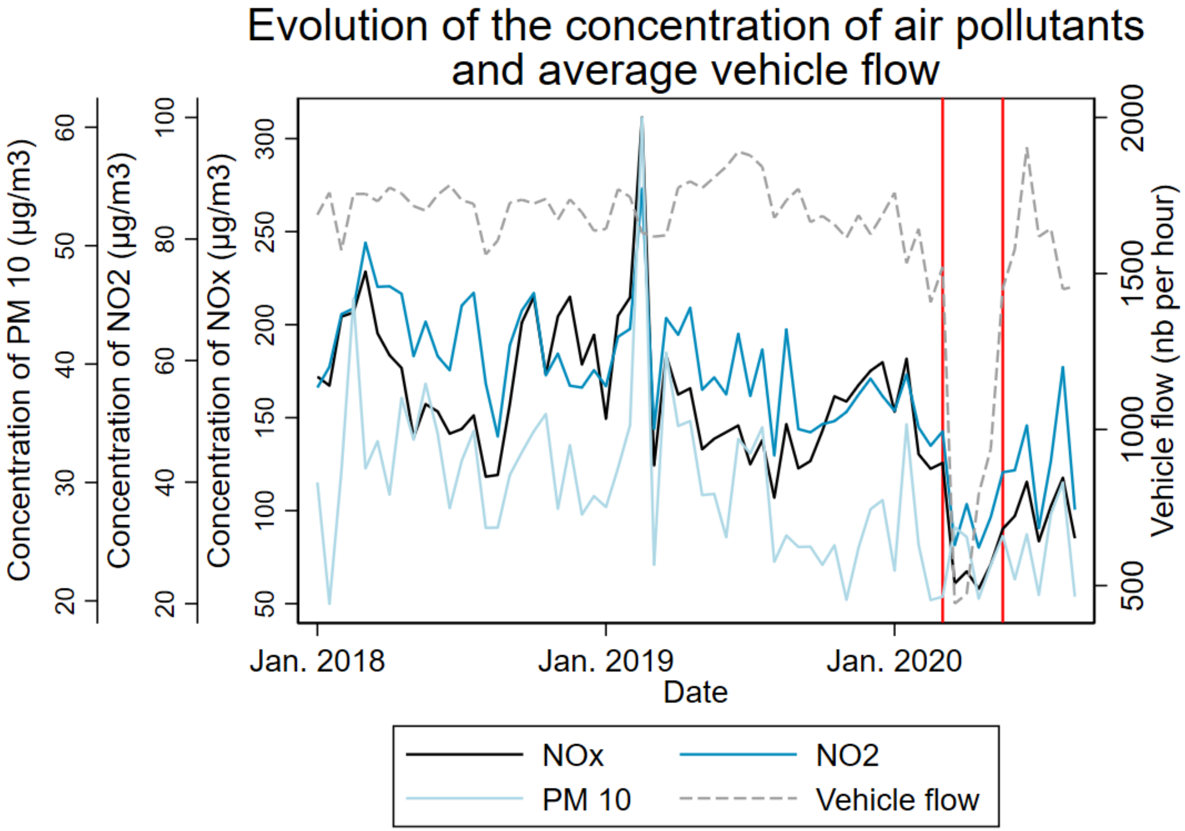
Around each air pollution station:
We built buffers 50, 100, 200 & 500m

Descriptive statistics (2)

Variables	# Obs.	Mean	St. Dev.	Min.	Max.
P_{10} (µg/m^3)	136,795	27.40	15.62	0.00	253.00
NOx (µg/m^3)	142,329	131.91	123.09	2.00	1,658.70
NO_2 (µg/m^3)	142,293	51.85	30.62	1.90	286.00
Flow100 (veh/h)	126,637	1,646.30	1,883.93	0.00	8,174.00
Occ100 (%)	152,155	10.62	10.87	0.00	96.15
Temperature (°C)	178,747	13.81	7.39	-7.00	41.70
Atmospheric pressure (HPA)	178,747	1,016.35	9.40	977.50	1,047.80
Wind speed (km/h)	178,732	3.12	1.43	0.00	12.10
Wind direction (360°)	178,732	181.92	103.42	0.00	360.00
Rainfall height (mm/h)	178,374	0.07	0.53	0.00	26.30
Relative humidity (%)	178,747	69.18	18.15	17.00	99.00
Electricity consumption (MW/h)	174,595	17,211.7	4,705.1	12.0	32,657.0
Lockdown (%)	178,747	4.06	19.74	0.00	100.00
End of Lockdown (%)	178,747	4.04	19.69	0.00	1.00

NB: according to Paris municipality, LDV + HGV = 17% (resp. 15% and 2%) of traffic flow in 2019

Descriptive statistics (3)



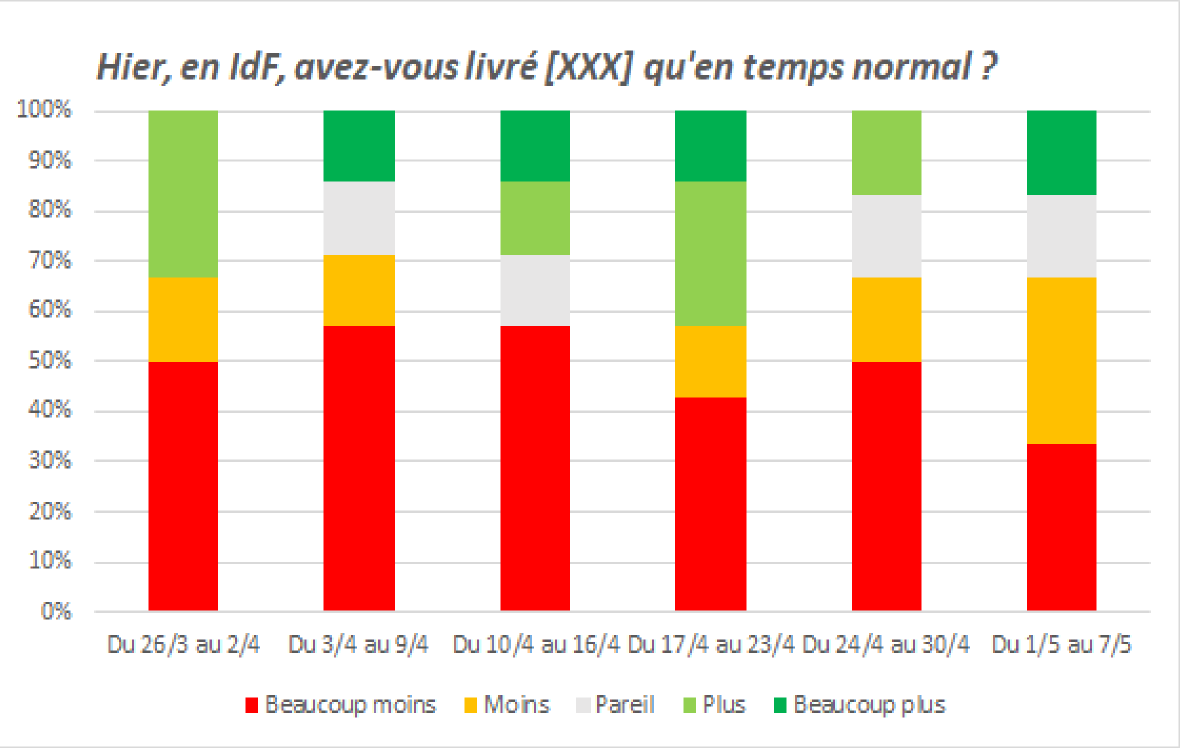
Comparing the lockdown to the same period one year before:

- Vehicle flow: - 41%
- NOx: - 45%
- NO2: - 36%
- PM10: - 26%

Comparing the 2 first weeks of the lockdown to the two previous weeks:

- Vehicle flow: - 71%
- NOx: - 52%
- NO2: - 39%
- PM10: + 29%

Carriers' survey (7 firms out of 14 that answered at least 4 times)



More than 50% of firms report "less" or "much less" activity during the lockdown

One can infer a decrease in freight flows of 30% during the lockdown

Order of magnitude consistent with the survey of FNTR (at the national scale)

Empirical strategy

- We only observe the **total traffic flow**
- **Idea:** use the change in the composition of traffic (share of cars versus freight vehicles) during the first COVID lockdown to assess the relative contribution of cars versus freight vehicles to air pollution
- The concentration of a given pollutant i in the air is:

$$K_i = \beta_{C,i} F_C + \beta_{T,i} F_T + X_i$$

where F_C is car flow, F_T is freight flow and X_i refers to other polluting sources

- Alternatively: $K_i = \beta_{Total,i} F_{Total} + X_i$ with $F_{Total} = F_C + F_T$

Empirical strategy (2)

- From these two equations: $\beta_{Total,i} = \beta_{C,i} \frac{F_C}{F_{Total}} + \beta_{T,i} \frac{F_T}{F_{Total}}$
- We only observe F_{Total}, so that we can only estimate $\beta_{Total,i}$ directly
- We also know that $\beta_{C,i} < \beta_{T,i}$
- During the lockdown, we expect an increase of $\frac{F_T}{F_{Total}}$ and decrease of $\frac{F_C}{F_{Total}}$
- If this is true, this should lead to an increase of $\beta_{Total,i}$
- We show that it is what happened during the lockdown

Empirical strategy (3)

- Econometric specification to estimate $\beta_{Total,i}$ before and during the COVID:

$$K_{i,s}^{t} = \beta_{Total,i} F_{Total,s,100m}^{t} + \beta_{Total,i}^{Covid} F_{Total,s,100m}^{t} \times 1_{Covid} + M^{t} + FE_{Covid} + FE_{year} + FE_{s,t} + \epsilon_{i,s}^{t}$$

where $K_{i,s}^{t}$ is the concentration of pollutant i at station s during hour t,

$F_{Total,s,100m}^{t}$ is the total vehicle flow in a buffer of 100m around station s at t

and M^{t} is a vector of weather characteristics in Paris at t

Empirical strategy (4)

- We then refine our methodology by taking into account:
  - the progressive come back of cars during the lockdown (increase in $\frac{F_C}{F_{Total}}$) through the inclusion of an additional term:

$$\beta^{Covid}_{Total,i,cum} F^t_{Total,s,100m} \times 1_{Covid}(t - t_{Covidstart})$$

  - the continuation of this progressive come back after the end of the lockdown with: $\beta^{Deconf}_{Total,i,cum} F^t_{Total,s,100m} \times 1_{Deconf}(t - t_{Deconfstart})$
  - the strike of Dec. 2019 - Jan. 2020 (opposite effects?)

Results (1)

	NO_2	P_{10}	NOx	NO_2	P_{10}	NOx	NO_2	P_{10}	NOx
Flow	0.006	0.002	0.019	0.007	0.003	0.029	0.004	0.002	0.021
Lockdown	-23.355	-4.716	-83.893	-10.942	0.212^{ns}	-34.420	-10.304	-2.435	-31.407
Flow_ Lockdown	0.007	0.002	0.010	0.008	0.003	0.018	0.007	0.003	0.015
Dummies	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	No	No	No	Yes	Yes	Yes
# Obs.	107,306	102,671	107,332	107,306	102,671	107,332	104,476	100,007	104,502
R^2 (within)	8.2	2.9	5.9	24.9	10.7	23.1	46.8	29.8	41.5

Note: all parameters significant at the 1% threshold (except if “ns”, for non significant)

Results (2)

	NO_2	P_{10}	NOx	NO_2	P_{10}	NOx	NO_2	P_{10}	NOx
Flow	0.004	0.002	0.021	0.004	0.002	0.021	0.004	0.002	0.021
Lockdown	-10.268	-2.517	-31.338	-10.405	-2.680	-28.971	-9.939	-2.965	-29.075
Flow_ Lock	0.006	0.005	0.014	0.006	0.005	0.014	0.006	0.005	0.014
Flow_ Lock_Cum	0.000^{ns}	-0.000	0.000^{ns}	0.000^{ns}	-0.000	0.000^{ns}	0.000^{ns}	-0.000	0.000^{ns}
EndLock	No	No	No	-2.904	-1.526	6.878	-2.448	-1.812	6.743
Flow_ EndLock	No	No	No	0.002	0.001	0.001^{ns}	0.002	0.001	0.001^{ns}
Flow_ End_Cum	No	No	No	-0.000^{ns}	-0.000	-0.000^{ns}	-0.000^{ns}	-0.000	-0.000^{ns}
Strikes	No	No	No	No	No	No	3.152	-4.742	-2.593^{ns}
Flow_ Strikes	No	No	No	No	No	No	-0.002	0.001	0.003
Flow_ Stri_Cum	No	No	No	No	No	No	0.000	-0.000*	-0.000^{ns}
Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# Obs.	104,476	100,007	104,502	104,476	100,007	104,502	104,476	100,007	104,502
R^2 (within)	46.8	29.8	41.5	46.9	29.8	41.5	47.0	30.0	41.5

Note: all parameters significant at the 1% threshold (except if "ns" or *)

Results (3)

	Bench.	50m	500m	Occ<30	LastYear	WEnd	Off-peaks
Flow	0.004	0.004	0.006	0.005	0.003	0.005	0.005
Lockdown	-10.304	-10.500	-7.050	-9.827	-8.986	-14.625	-9.904
Flow_ Lockdown	0.007	0.007	0.008	0.008	0.006	0.009	0.008
Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# Obs.	104,476	88,919	137,712	99,516	37,803	29,605	69,190
R^2 (within)	46.8	46.5	45.5	47.0	47.1	46.4	44.1

Note: all parameters significant at the 1% threshold

Estimates for NO2, but similar results for NOx and PM_{10}

Back-of-the-envelope computations (1)

So far, we had:

$$K_{i,t} = \beta_{Total,i} F_{Total,t} + X_{i,t} = \beta_{C,i} F_{C,t} + \beta_{T,i} F_{T,t} + X_{i,t}$$

which we transform into:

$$\boxed{K_{i,t} = \beta_{Total,i} F_{Total,t} + X_{i,t} = \gamma(\rho_{C,i} F_{C,t} + \rho_{T,i} F_{T,t}) + X_{i,t}}$$

We estimate:
- $\beta_{Total,i}$ from the regression,
- $\rho_{C,i}$ and $\rho_{T,i}$ from the COPCETE software of vehicle emissions,
- averages of $F_{Total,t}$ over the COVID and no-COVID period from the traffic counter database,
- averages of $F_{C,t}$ and $F_{T,t}$ over the no-COVID period using a survey led by Paris city and over the COVID period using the Logistics City Chair's survey of carriers

Back-of-the-envelope computations (2)

From equation:

$$K_{i,t} = \beta_{Total,i} F_{Total,t} + X_{i,t} = \gamma(\rho_{C,i} F_{C,t} + \rho_{T,i} F_{T,t}) + X_{i,t}$$

We compute γ

We then deduce the estimated contribution of freight to traffic pollution in Paris:

$$\boxed{\frac{\gamma \rho_{T,i} \bar{F}_{T,noCOVID}}{\bar{K}_{i,noCOVID}}}$$

where $\bar{F}_{T,noCOVID}$ and $\bar{K}_{i,noCOVID}$ are averages of $F_{T,t}$ and $K_{i,t}$ over the no-COVID period

Back-of-the-envelope computations (3)

NB: Emissions from freight vehicles are, on the average, twice those of cars

The contribution of freight transport to the concentration of NOx has been multiplied by 3 during the lockdown (by 2 in the case of PM10)

	March-May 2019		During Lockdown	
Total vehicles flow (veh/h)	1,725		568	
Share of freight vehicles	17%		36%	
Freight vehicles flow (veh/h)	293		568 (-30%)	
	NO_x	P_{10}	NO_x	P_{10}
Estimated parameters	0.021	0.002	0.036	0.005
Pollutants concentration (μg/m^3)	136.4	30.2	50.1	22.9
Due to total road transport (%)	26.6%	11.4%	40.8%	12.4%
Due to road freight vehicles (%)	7.7%	3.7%	21.6%	7.0%

Conclusions

- COVID lockdown modifies the link between traffic and pollution concentration
- We provide evidence that this result is due to an increase in the share of freight vehicles within the total traffic flow
- We show that, even when data is lacking, it is possible to estimate the share of air pollution due to freight traffic.
- In the case of NOx, the contribution of freight vehicles in pollution due to traffic rose from ¼ to 1/2 during the COVID lockdown

Forthcoming

- Take into account the accumulation of pollution through time and the role of speed
- Mini-survey to re-estimate the share of freight vehicles during the COVID period
- Verify the methodology using the post-COVID period for which open data on modal shares is available
- Health application