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REGULATING TRAFFIC TO REDUCE AIR POLLUTION IN GREATER CAIRO, EGYPT

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Abstract

Automobile emissions in Greater Cairo are considered the main source of local air pollution. This chapter examines transport mode choices and tries to evaluate the impact of traffic regulation on reducing suspended particulate matter (PM10). The empirical analysis is supported first by a demand analysis that builds upon household level data collected in Greater Cairo. Results show that most transportation modes are in fact complementary at the household level. Second, the chapter analyzes the pattern of PM10 emissions from 2002 to 2008 using data from monitoring stations in Greater Cairo. A fixed effect emission model is estimated, relating PM10 concentration to motor vehicle data, seasonal differences, peak hours and implementation of Egyptian policies regarding atmospheric pollution. Estimation results reveal a limited but significant impact of environmental policies on ambient PM10 concentration, although the implementation of some measures remain slower than expected in order to cope with the rapid increase of traffic.

ملخص

تعتبر "انبعاثات" عوادم السيارات في القاهرة الكبرى المصدر الرئيسي لتلوث الهواء فى المدينة . لذا تم التركيز فى هذا الفصل على دراسة خيارات وسائل النقل ومحاولة تقييم تأثير تنظيم حركة المرور على الحد من الجسيمات العالقة (PM10). و يدعم التحليل التجريبي اولا تحليل للطلب الذي يعتمد على البيانات التي تم جمعها على مستوى الأسر في القاهرة الكبرى. و لقد أظهرت النتائج أن معظم وسائل النقل هي في الواقع تكميلية و ذلك على مستوى الأفراد. ثانيا ، يحلل الفصل نمط انبعاثاتPM10 في الفترة من 2002-2008 باستخدام بيانات محطات الرصد بالقاهرة الكبرى. وفى هذا السياق تم تقدير نموذج تأثيرالانبعاثات الثابتة، و الذي يربط بين تركز PM10 و بيانات السيارات، والاختلافات الموسمية، وساعات الذروة وتنفيذ السياسات المصرية فيما يتعلق بالتلوث الجوي. و يكشف تقدير النتائج عن وجود تأثير محدود لكنه مهم للسياسات البيئية على تركز PM10 المحيط ، و ذلك على الرغم من استمرار بطء تنفيذ بعض التدابير أكثر مما كان متوقعا من أجل التعامل مع الزيادة السريعة في حركة المرور.

1. Introduction

Among the Arab countries, Egypt is in a category of its own. By far the largest in terms of population, it faces commensurably huge challenges in regard to its environmental and economic development. With a huge State apparatus and a massive bureaucracy, it is still lagging behind on environmental protection. However, the Egyptian Environmental Affairs Agency (EEAA) has made good achievements in terms of combating air pollution. Sources of air pollution in Egypt are several including: cement, industrial pollution, rice cultivation, oil refineries, bricks, iron and steel, power stations, and motor vehicles.

Additionally, Egypt's dry climate with its limited rainfall and prevalence of desert areas causes seasonal sand-laden weather. Additional air pollution has resulted in the chronic Black Cloud phenomenon since 1999. Efforts made by the EEAA to improve air quality concern mainly the cement industry which is an important economic sector of the Egyptian economy, but also agricultural waste management by controlling the bulk burning of rice straw. However, vehicle exhaust fumes are a major source of air pollution especially in Greater Cairo (GC) where traffic density is high. GC is considered one of the largest megacities in the World. It comprises 22% of Egypt's population(about 18 million inhabitants) and stretches over five different governorates (Cairo, urban Giza, urban Qalyobiya, Helwan and 2 new cities in the 6th of October governorate).

Regarding vehicle exhaust fumes, the EEAA has embarked on a number of projects to control air pollution resulting from vehicle exhausts such as: banning leaded gasoline, projects to replace old taxis, testing programs for vehicles on road and in license and registration units, promoting natural gas as an alternative to petrol, garage relocation projects as well as protection programs from motorbike exhausts. Another instrument to improve air quality and reduce fuel consumption is the newly implemented traffic legislation. However, fuel subsidies do not seem to be incentive-compatible to mitigate greenhouse gases (GHG), probably because of a sub-optimal subsidy level. Since the current level of annual emissions of GC is about 13 million tons of CO_2, any income growth that stimulates the demand for car ownership is likely to increase pollution including CO_2 emissions. Although it is generally understood that policies to reduce GHG emissions can also have near-term positive and negative ancillary side effects on public health, eco systems and land use, these side effects have not been well characterized or integrated into the policy analyses of mitigation. As is apparent so far, the EEAA has not been very successful in regulating motor vehicle traffic as a means of reducing GHG emissions.

The following section presents the basic facts and the existing policies at play in Greater Cairo, Egypt, for controlling atmospheric pollution due to vehicle exhaust fumes. In Section 3 we discuss the theoretical advantages and drawbacks of environmental policies dedicated to controlling atmospheric pollution proposed in the economic literature. We also tackle issues of implementation, cost control and technical barriers to implementation in the Egyptian context. In Section 4 we propose an ex post evaluation of Egyptian policies, by evaluating first the range of policy instruments compared to the economic literature in other national settings, and second, by proposing an empirical analysis for Egyptian data. The objective is to determine whether the implementation of targeted environmental policies in Greater Cairo since 2008hadbeen effective in reducing PM10 emissions. Regarding atmospheric pollution, emission trends are statistically analyzed using hourly PM10 records from air-quality monitoring stations in Greater Cairo from 2001 to 2008. We also investigate the potential for transportation-mode diversion at the household level by estimating a demand system for major transportation modes. Section 5 proposes policy options that are a compromise between the needed environmental objectives, the implementation issues and cost budget of the policies, and the expected performance of the economic instruments in terms of exhaust fume reduction.

2. Atmospheric Pollution in Greater Cairo and Existing Policies

Air pollution due to automobile emissions is a major concern in most fast-expanding cities in developing and developed countries alike. Vehicle traffic volume and associated emissions obviously depend on a range of factors such as population size, fuel consumption per capita, the proportion of the population owning motor vehicles, annual average distance travelled, the age distribution of motor vehicles, etc. The degree of air pollution is particularly problematic in cities where small-sized vehicles are the main means of commuting and transportation due to insufficient mass transportation alternatives.

Between 1996 and 2006, the population of Egypt between has increased from 59 to 73 million with an average annual growth rate of 2.04%. The Greater Cairo Area hosts the largest share of population, economy, industry, and human resources in Egypt. With a population of about 17 million in 2006, and a fast urbanization rate (expected to reach 24 million in 2027), GC is one of the largest megacities in the world and is Egypt's largest agglomeration (22% of Egypt's population). It includes three governorates: Cairo, urban Giza and urban Qalyobiya. With such a large population, the need to have an efficient and reliable public transport system is unequivocal. Although the current urban transport system is highly diversified in GC in terms of supply and related infrastructure and facilities, it still requires significant improvements to reduce the existing level of aggravated traffic congestion and carbon emissions.

Traffic congestion is a severe problem in GC with substantial adverse effects on personal travel time, vehicle operating costs, air quality, public health, and business environment operations. Based on rough estimates from 2003, it is expected that without investments in urban transport, the annual emissions will increase from a current amount of about 13 million ton CO_2 to about 16 million in 2022.Additionally, the average trip speed of all modes of travel would decrease from 19.0 km/h to 11.6 km/h and the average journey to and from work would take more than 1.5 hours. According to these estimates, the total economic cost of this "do nothing" scenario is estimated at LE7.5 billion (US$ 1.6 billion) per annum.

Air pollution may also have severe effects on human health causing respiratory and cardiovascular diseases, and may entail serious effects on child growth and premature death. Larsen (2011) estimates annual mortality from PM2.5 in large Egyptian cities in 2008 and its related costs. Given the share of GC population, the mortality due to PM2.5 amounts to eight percent which translates to a total economic cost of LE14.7 billion (US$ 2.99 billion) per annum.

2.1 The patterns of atmospheric pollution in Greater Cairo

The number of motor vehicles in Egypt was 3.4 million in 2003 and reached 5.8 million in 2010, of which nearly one half is in Greater Cairo. In 2009, there were about 115,300 registered taxis in GC, with 24% and 58% aged respectively 32 and 22 years or more (World Bank 2010). The causes of traffic congestion are complex, as are the range of possible policies and investments that could be used to address the problem. In GC, about two-thirds of all motorized trips are made by public transport (mostly taxicabs and minibuses), and there are, therefore, tremendous opportunities for improving traffic congestion through accelerated modal shift to mass transit systems.

The Ministry of State for Environmental Affairs (2009) has estimated that vehicle emissions represent about 26 % of total pollution load for suspended particulate matter (PM10) in GC, 90 % for carbon monoxide (CO) and 50 % for nitrogen oxides (NOx). About 40 % of national transport emissions (13 million ton CO_2-equivalent) are attributed to the GC region alone (World Bank 2010), which represents about 50 % of all motorized vehicles in Egypt. To perform an assessment of existing policies aimed at curbing atmospheric pollution sources from motor vehicles in GC, it is possible to compare average pollution measures both before and after regulation has been implemented. Daily records from air quality monitoring stations are regularly collected from various areas across GC. Currently, monitoring emissions in GC is implemented through 20 measurement stations spread throughout the metropolitan area. Five of those are identified as traffic stations, six as residential, four as industrial, two as urban and two as mixed stations. The 20th station is placed in a remote area and its readings serve as a benchmark for emission levels. Each station measures one or more pollutants such as CO, lead, NO_2, SO_2, NOx, PM2.5, PM10 and O_3. Ten of the above stations are electronic and so they have daily averages; data collected from the other ten stations are weekly averages. The most reliable series are available from 2003 onwards; however, some of the stations have only been operating since 2005.

To identify intra-day variations in pollutant loads, we collected data from 16 air-quality monitoring stations in the GC region on an hourly basis, for the years 2001 to 2008 from EEAA. The panel sample is strongly unbalanced given that the number of stations recording specific pollutant emissions is increasing over time. Table 1 presents annual average concentration of suspended particulates (PM10) in 12 selected sites, for the years 2001 to 2008. As can be seen from this table, data is complete in only four sites: Abbasseyia, Fum El-Khalige, Kolaly and Tebbin, while years 2007 and 2008 have the most complete dataset. The data from Giza has been deleted because of a large proportion of outliers from this monitoring station. PM10 peaks in year 2003 especially at the Kolaly site. Moreover, the level of PM10 shows volatility over time. While examining a special year such as 2008 it is evident that the most polluted area is Shubra which is a heavily populated and congested district. A caveat is in order here; all PM10 levels are higher than the permissible health level of annual average ambient concentration of 70 and 20 $\mu g/m^3$stated by the Egyptian Environmental law and the WHO guideline limits, respectively. For the same years, we also compute the average PM10 concentration over all stations, by hour and season (quarter). Figure 1 (and table A1 in the Appendix) illustrates that the highest PM10 concentration is between 7 and 10 in the morning for the first and fourth quarters, while the peak, for the second and third quarters is between 9 and 11 pm. It should be noted that this is the summer period in Egypt where temperature soars. Moreover, schools and universities are on break and people tend to go out in the evening when the weather becomes more pleasant. In addition, the third quarter exhibits the lowest levels of PM10 concentration since this is the period when Cairo inhabitants tend to leave the city for their summer vacation homes.

2.2 Existing policies in Egypt

Several programs have been recently implemented to deal specifically with atmospheric pollution from motor vehicles, directly or indirectly through mass public transit extension or improvement.

2.2.1 Converting public sector vehicles to natural gas

In 2004 the EEAA surveyed all public sector vehicles to determine the ones that may be converted to natural gas. Out of 5,000 targeted vehicles, 2,274 gasoline public sector vehicles have already been converted to natural gas. The remaining 2,684 vehicles were technically inspected to determine the possibility of conversion.1,716 vehicles proved to be fit for the process and the conversion is currently underway.

2.2.2 Replacing old taxicabs scheme

To achieve compliance with the safety limit of emissions from exhaust pipes, a pilot project was first conducted in 2007 for 35 year old (or older) taxicabs in GC. These vehicles were replaced by natural-gas taxicabs with a 6-year loan guaranteed by the Government and a six percent interest rate covered by the MSEA. This successful project was extended in 2008 with a first phase to convert 1,000 taxicabs (aged from 29 to 48 years) with a subsidy LE10,000 per vehicle from the Ministry of Finance. According to the Ministry of Interior, about 18 % of old taxicabs in the GC region have already been replaced (up to August 2009). The project is now targeting all old taxicabs in the GC (aged 20 years or more) with a LE5,000 subsidy from the Ministry of Finance and a rebate on new cars from participating car companies, as well as low interest rates from participating banks (Ministry of Finance 2009).Expected emission reduction from this program alone is in the range [1.3, 2.3] million ton CO_2-equivalent from 2010 to 2019.

2.2.3 Inspecting vehicle emissions as part of vehicle licensing

Vehicle licensing has been coupled with inspection for emission measurement. According to Law 2008/121, mass transport vehicles (taxicabs, microbuses, trailer trucks and buses) more than 20 years old are not eligible for license renewal or a new operating license unless they pass the emission standard testing. Private owners of mass transport vehicles have therefore strong incentives to dismantle their vehicle or convert it to private use.

This is one of the justifications for a new scrapping and recycling program backed by the World Bank, as part of the Carbon Finance Program. The International Bank for Reconstruction and Development (IBRD) will join with the Ministry of Finance to purchase Certified Emission Reductions (carbon funds) generated by GC taxicabs participating to the program. The sales proceeds of these certificates will be used to cover part of the program cost to the Ministry of Finance. New vehicles will be equipped with catalytic converters, with a LE5,000 down payment, exemption of customs fees, an interest rate below market rates from participating banks, an option to participate in an advertising scheme, and an insurance program for all new taxi vehicles. Accounting for all the exemptions and financial advantages, the World Bank estimates that the cost for the owner will be between LE390 and LE1,205 per month depending on the car model. The expected reduction in CO_2-equivalent emissions ranges between 17,000 and 35,000 tons per year for each participating vehicle in the GC region. The program will start targeting microbus and bus vehicles from 2010 to 2012 (after taxis in 2009, with about 5,000 vehicles joining the program every two months).

2.2.4 Inspecting motor vehicles on the road

In 2008, about 45,000 diesel and gasoline vehicles have been inspected for exhaust emissions on the road, with a pass rate of about 70%. Legal action in the framework of Law 4/1994 can be taken against vehicle owners who fail the test, with a mandatory repair, technical inspection and a re-test procedure.

2.2.5 Inspecting Cairo transport authority buses

Some 4,436 buses were tested in 2008, with a pass rate of about 43% (out-of-order buses in garages represented 25% of the total). A further inspection of 4,020 and 3,677 buses was undertaken in 2009 and 2010, respectively. As a result, about 20% of the buses are yearly dismissed from service.

2.2.6 Reducing motorcycle emissions

This program is driven by the higher emission rate of hydrocarbons from two-stroke engines compared to cars. There are about 200,000 motorcycles in GC, which emit about 112,000 tons of pollutants per annum. Simultaneously, production of two-stroke engine motorcycles has been forbidden in Egypt since December 31, 2007, and imports of such vehicles has been forbidden since January 11, 2008.

2.2.7 Extending the existing public transportation system

The government's vision for transforming the urban transport sector in GC is reflected in the Greater Cairo Urban Transport Master Plan (JICA 2003). The master plan studies provided a new framework for considering an integrated urban transport system that emphasized putting "people's mobility before that of vehicles." The master plan took account of three "missions" for the urban transport:

- a safe and environment-friendly transport system that would significantly reduce the carbon signal, focusing on modal shift toward low carbon mass transport systems;
- an economically effective urban transport system; and
- an equitable people's mobility.

The Greater Cairo Urban Transport Master Plan has allocated investments of up to US$17 billion for an integrated urban transport system including mass rapid transit: metro (US$2,724 million), suburban railway (US$2,550 million) and expressways (US$7,875 million).The government has already completed lines # 1 and 2 of the underground metro totaling 65 km (with a commitment to complete line # 3 by 2012 and line # 4 by 2017, totaling 70 km). The combined urban transport program is expected to result in emissions reduction of between 17.7 and 19.5 million ton CO_2-equivalent from 2010 to 2019. Computations are based on an assumed average number of vehicle-kilometers travelled of about 38,816 per year.

The World Bank has also been assisting the government in developing its urban transport policy, and has prepared an Urban Transport Strategy for the Greater Cairo Region (World Bank 2006) which highlighted the need for facilitating modal integration, facilitating user-oriented public transport, and introducing traffic demand management. The World Bank has also been assisting in prioritizing interventions and has committed financing to urban transport projects through IBRD, the Clean Technology Fund, and carbon finance sources to contribute to the cost of short-term investment needs based on the above government plans.

2.2.8 Tariff of vehicle licensing

In May 2008, the licensing tariff scheme was revised and was considerably increased. The new tariffs became two to ten times higher the old tariffs depending on the vehicle registry, type and capacity. For example, the tariff changed from LE16 to LE116, LE23 to LE143, LE25 to LE175 and LE120 LE to LE1,000 for cars of 1030cc, 1320cc, 1630cc and 2030cc, respectively. This was paired with an increase in fuel prices of about 35 to 57 percent depending on the octane. Though the increases were implemented in order to raise government revenues, they had a clear impact on the car market which witnessed a 35 percent decrease in car sales. This scheme may also have an indirect incentive effect and we may try to track its effect on mitigating air pollution.

3. Environmental Policies for Atmospheric Pollution

From an environmental economics' point of view, reducing automobile air pollution can be achieved either by regulatory (command-and-control) policies, or by policies based on economic instruments (market-based). In the longer run, however, investment strategies in mass public transportation systems are also part of general urban management and planning, and sustainable development policies.

3.1 Regulatory or economic instruments

Vehicle exhaust fumes as a major contributor to GHG and to local atmospheric pollution are generally considered nonpoint source, as the number of polluters is typically very large, and individual contributions to ambient pollution are too costly to measure and monitor. This means that a) standard command-and-control policies may not always be feasible because of possibly prohibitive control costs; b) dedicated policy instruments for controlling nonpoint source pollution need to be considered.

The regulation of atmospheric pollution originating from car vehicle exhausts falls into the category of nonpoint source pollution because there is a very large number of individual, fairly homogeneous contributors to ambient pollution. It should be noted that emissions of this kind could be considered point source if the actual impact of individual contributions could be assessed with sufficient accuracy, and if monitoring and controlling each individual contributor could be technically and economically feasible.

The first route for the environmental regulation of nonpoint source pollution originates from the literature on moral hazard in teams. In principle, assuming a Nash-Cournot and risk-neutrality behavior of polluters, a tax-subsidy scheme indexed on the difference between a standard (or a socially optimal pollution level) and an observed ambient pollution concentration level will yield the first-best solution. This is because polluters are given incentives not to deviate from a "reasonable" behavior and the collective punishment (fine) applying to the population of polluters is very large.

Because pure nonpoint source policy instruments are very difficult to implement (social consequences of prohibitive collective punishment if ambient concentration is above the standard, legal aspects linked with the absence of proof for individual responsibility), alternative policy instruments are recommended. Standard policy instruments like environmental standards, taxes and subsidies can be used to motivate economic agents to modify their behavior towards the socially desirable outcomes; these instruments being applied not to pollution itself, but to observed variables related to emissions. This is the principle of indirect regulation according to which a second-best policy can be based on taxing or subsidizing pollution-related production or consumption equipment at a much lower cost.

In our case, some vehicles or fuel sources could be taxed or subsidized depending on their average pollution-specific factors. In particular, fuel taxes would certainly reduce emissions, but the optimal level of these instruments would steeply increase the monetary cost of travel per trip and are, therefore, politically difficult to implement. An alternative is to promote voluntary agreement type policies where agents are given incentives to change their existing vehicles for a less polluting one, or to adopt a pollution-abating technology. These second-best policies are in practice a good compromise between implementation and controlling costs on the one hand, and incentive power and environmental performance on the other.

As is well known in environmental economics, the most efficient way to achieve a socially-optimal pollution level is to make polluters pay the social damage of their activity by charging a tax equal to the social marginal damage cost and the private cost of the activity. Taxing car pollution damage through environmental road pricing would then ideally be conducted by evaluating the sum of damages incurred by motor vehicles, which depends on vehicle emissions, location, and weather. Vehicle emissions themselves depend on the emission rate, the distance travelled, and therefore on the vehicle characteristics (age, fuel type, etc.) and external characteristics (temperature, road conditions, wind speed and direction). An optimal Pigovian tax is not feasible as too many parameters would have to be measured, and the visibility for the polluter would be too low to infer significant changes in driving behavior and decisions. More importantly, the fact that pollution (and ultimately damage) depends on a wide range of factors with strong interactions implies that an integrated approach to regulating motor vehicle pollution is necessary and would save on policy costs(see Molina and Molina 2004). As discussed in Sterner (2003), feasible policies need to trade off complexity costs with the sub-optimality of a simpler fee system. Such simpler tax schemes can consist of area pricing (depending on location alone), as in many European cities and Singapore, mileage tax and road toll (depending on distance travelled and possibly type of vehicle) as in Germany for expressways and Sweden for diesel-fueled vehicles (mileage tax), differentiated vehicle tax (sales tax conditional on the existence of a catalytic converter).

Another factor that may affect vehicle emissions is road congestion. This in turn creates economic costs of congestion that are not only due to increased average travel time but also due to increased travel time uncertainty. But significant costs originate from energy inefficiency, poor air quality, poor road safety, and higher vehicle operating costs.

In order to reduce the negative impacts of congestion that are closely related to poor air quality, governments across the world have resorted to a variety of instruments of different types, those may be summarized as: (i) behavioral instruments such as staggering work start times, (ii) fiscal instruments,(iii)investments instruments, that may be manifested in improving traffic management measures, increasing the supply of public transport or the capacity to accommodate vehicles,(iv) regulatory instruments, both technical as well as economic, and (v) the use of urban planning to ease congestion. Orubu (2004) lists the main policy instruments considered in the case of Nigeria with comments on their implementation details (see Table 2).

The adequacy of each of these instruments varies across countries. Nevertheless, countries that have succeeded to curb congestion have done so only after adopting a coherent package combining several of the above instruments. For instance in London, the combination of tax measures (congestion tax) and improved public transportation (particularly buses …) have yielded significant results. Transport for London estimates that the congestion tax system in London has led to a reduction in city-center traffic by 12%, of which about 60% shifted to public transportation. Meanwhile, experience shows that these instruments, applied independently, are not cost effective and would not achieve desired results:

a. Fiscal instruments alone, such as increasing fuel taxes, could hamper economic growth by suppressing travel demand, particularly when there are no adequate public transportation alternatives. In addition, fiscal measures tend to be regressive, in most cases, from a welfare point of view. Arnott et al. (1994) argue that congestion charges disproportionally impact the travel choice of lower income households, while Evans (1992) argues that low-income groups can benefit from congestion charges if the revenue generated is invested in public transportation.

b. Regulatory measures are far from sufficient on their own. Regulatory instruments contribute to improving the quality and efficiency of the sector, through organizing the use of public space and through redistributing traffic demand on various modes. This, however, requires that these modes and the associated infrastructure already exists and at an adequate capacity.

c. Investments alone, particularly in urban road infrastructure, may not necessarily be the most cost-effective means of reducing congestion. Nelson et al. (2006) have shown that each dollar of road spending reduces congestion costs by 11 cents. This low impact of public spending on actual congestion cost reduction may be explained by many factors: poor road design that causes excessive maintenance costs, slow and inappropriate response to changes in demographic factors in the city, inflated costs to the public sector, or simply by pork barrel politics. Hence, a cost-effective congestion cost reduction strategy requires more than additional public spending.

d. Planning—particularly urban planning— is an important instrument; however, it is rarely effective alone in ex post situations where urban density has reached high levels, such as in GC. In addition, the impact of urban planning on travel patterns, while important, takes a long time to materialize. Moreover, the fast rates of urbanization in most developing countries, with cities growing along major transport corridors, precede the development of the necessary infrastructure and further exacerbate congestion.

e. Behavioral instruments are relatively new and are still being tested in developed countries. The effectiveness of these instruments remains to be seen.

Although it is rarely considered for environmental purposes but for revenue generation instead, taxing gasoline or diesel is an interesting economic instrument for modifying drivers' behavior in the long run. Many empirical studies have shown that the short-run price elasticity of fuel demand is low, but once long-run adaptation through expenditures on more efficient vehicles is considered, the sensitivity to price is higher. In a couple of surveys by Sterner and Franzen (1995) and Rogat and Sterner (1998), short-run price elasticities of fuel range from -0.10 to -0.31, whereas long-run elasticities are between -0.50 and -1.39 (depending on the estimation method and the country considered). However, a fuel tax is not an optimal instrument by nature for regulating atmospheric pollution due to local pollutants, because it only induces a reduction in fuel demand when transport substitutes exist (mass public transit in particular), and does not specifically target the emission contents of fuel. This implies that the incentives to invest in pollution abatement technologies for motor vehicles may be missing. A possible solution is of course to consider a tax system based on emission contents of fuel (NOx, and $CO_{2,}$ for example). Because direct measurement (electronic) devices are far too costly to install and manage, a simplified system is used instead, based for example on the type of fuel (diesel, gasoil, gasoline, etc.) Obviously, the complexity of a direct monitoring system for an emission tax implies that a fuel tax is often an imperfect substitute. In this case, a dual system taxing fuel and imposing standards on the maximum age of the vehicle can be considered suboptimal policies, but which are nonetheless much easier to implement.

An issue concerning fuel taxes is the relationship between fuel prices and demand. It is commonly observed that countries which have been promoting high fuel consumption patterns for residential and commercial purposes are also the ones where fuel taxes are lowest. Causality seems to go in the opposite direction as expected, namely from consumption level to fuel prices, due to political considerations and the influence of special-interest groups.

A particularly important determinant of the transport mode decision is the price of petrol or diesel for private cars and taxis. In Egypt, subsidies on fuels have been in place for decades, but in 2006, following a sharp increase in demand from industries and households, a program to reduce energy subsidies was initiated. Subsidies were removed from energy-intensive industries (petrochemicals, steel and cement) in the fiscal year 2007-08. Remaining energy subsidies still cost the government about US$5.89billion in 2009 (70% of its total subsidies).The original plan was to phase out subsidies for electricity and gasoline completely by 2012, but since the onset of the financial crisis, the government's objective was modified to preserve economic and social stability. As a consequence, the financial plan to dismantle the subsidy program completely was postponed for the year 2014 instead of 2012. Raising energy prices is a political issue: as 2010 was an election year in Egypt, the political objective was modified to postpone removal of subsidies for non-energy intensive industries by the end of 2010, starting in July 2010. However, after the 25th of January Revolution in 2011, the government is now inclined to increase subsidies in response to social demands. Subsidies on domestic energy prices have started declining since 2004, but up till now, it is not clear whether the removal of subsidies would also affect energy for households. Some Egyptian economists estimate that a total elimination of subsidies (industry and households) would raise inflation by 7%.

3.2 The properties of regulatory and economic instruments for controlling nonpoint source pollution

Economic instruments are generally considered the most efficient ones in promoting a significant change in agents' behavior through a modification in price or cost ratios across alternatives. Of course, this potential comes at the price of acceptability and possibly equity, which can seriously limit the effectiveness of policies if implementation is opposed by special-interest groups or wide categories of the population. Another important issue concerns the efficiency of such policies when based on measured levels of activity. If a tax-based policy for instance requires an accurate monitoring system for individual polluters to be fully effective, then management costs can be prohibitive and a second-best policy based on indirect (proxy) but observed variables could be preferred.

Voluntary agreements for environmental protection have been advocated for agricultural and industrial nonpoint source pollution. Mixed results have experienced in such cases because of insufficient participation rates in some countries or sectors. The general idea is to promote a collective arrangement among polluters with a predetermined objective in terms of ambient pollution (e.g., achieving local compliance with an emission standard).This arrangement can be either self-regulatory or proposed by an environmental regulator as a contract with the group of polluters (for instance, an industrial producers' union or an agricultural cooperative).For example, a policy for pesticide regulation in Holland started in 1991 with a threat to impose a tax on pesticide use if a collective arrangement was not reached by Dutch farmers. The existence of such a threat allowed for a collectively-organized change in practices, resulting in a 46 % reduction in pesticide use by the year 2000. In the case of motor vehicle emissions, however, it is unlikely that private owners can design such a voluntary agreement because of the number of agents involved. However, this option remains valid for bus transport or taxi companies which could anticipate the implementation of a tax-based or an emission standard-based policy.

Tradable emission permits have been applied in some instances as an interesting alternative to economic instruments such as taxes and subsidies. The general idea is to transfer pollution rights to individual polluters, who can exchange their rights according to their valuation of the benefits attached to activities associated with pollution. In cities where partial bans on car traffic have been applied according to the type of the car plate (odd or even), a car driver entitled to travel a particular day can then exchange his/her pollution right with another driver. Another possibility is to organize an auction with a predetermined number of travel rights for private car owners. Receipts from such auction could then be collected by the government and help finance public transportation projects. This policy would be more efficient in economic terms, as authorized drivers would be the ones with the highest valuation of the right to travel.

According to Eskeland and Feyzioglu (1997), the partial driving ban implemented in Mexico City actually increased total driving after an initial adjustment period of 6 months. Although the "day without a car" program seemed interesting, because of easy compliance monitoring (through car plate inspection), fairness (traffic ban independent from car model) and incentives to switch to the public transportation system, the program was a failure. In this particular case, the traffic regulation was seen not just as a traffic ban but as an issue of driving (and pollution) permits for 6 days a week. Households were then given incentives to buy an additional car, often an older and more polluting one, thereby increasing overall fuel consumption, congestion and pollution. The policy turned out to be unfair because wealthier households could buy additional vehicles more easily. And because the Mexico City public transportation system was already over-crowded, drivers were not encouraged to switch massively to public transport modes.

One noticeable issue concerns the competition between private motor vehicles or taxis and public mass transportation (metro). If the latter is not expanded through investments in infrastructure, then the probability to use motor vehicles is likely to remain the same (assuming prices are unchanged). If then, a subsidy for scrapping old taxicabs is introduced; the emission factor for this category of vehicles will drop, resulting in a net benefit in terms of emission reduction. On the other hand, the number of taxis in circulation will remain stable, so that congestion issues are still unsolved. In the short run when the number of trips and mass transit infrastructure are constant, the reduction in emissions from the replacement policy should be immediate. In the longer run however, with an expected increase in population, congestion will increase and so will idling periods for motor vehicles. This implies that planned extensions for the mass public transit infrastructures need to be in place, otherwise a part of the reduction in emissions attributable to the vehicle scrapping program is likely to be offset by the increase in traffic congestion.

Reasons may be grouped into different categories including bad rules (in the sense of not being incentive compatible), weak enforcement or ineffective penalties. The problem is made worse if the prevailing policy conditions in a country like Egypt are such that the economy is not competitive and the bureaucracies are not totally honest, well-informed and sufficiently well-funded to carry out their responsibilities. Under such circumstances it is not surprising to find out that repeated attempts to control air pollution often yield disappointing results.

According to Faiz et al. (1995), four broad strategies should be pursued for regulating urban pollution in developing cities:

- - improve vehicle technology through vehicle replacement scrapping, inspection and maintenance;
- - use cleaner fuels;
- - control and manage traffic; and
- - improve urban transportation infrastructure.

These four strategies, when considered simultaneously, would imply the following measures to be implemented:

- Motor vehicle scrapping programs.
- Inspections on-road and on license registration and renewal.
- Imposing area taxes and/or partial traffic bans.
- Investing in mass transit infrastructure for better alternatives to private vehicles.

3.3 The Parry and Timilsina study

A recent simulation experiment has been proposed by Parry and Timilsina (2010) on the impact of various policy instruments on traffic choices in the GC area. Based upon a model specified for Mexico City (Parry and Timilsina 2009), the authors of the study calibrate a transportation model to evaluate the impact of alternative policies to reduce traffic and congestion. More precisely, policies include a gasoline fuel tax (or a reduction in fuel subsidies for Egyptian households), a mileage toll for autos, a toll tax for microbuses, and modified bus and rail fare pricing. The optimal level of policy instruments is computed using a Pigovian approach, each one being the combination of externalities related to emissions (local and global), traffic congestion and road accidents. The authors calibrate the optimal pricing model from Egyptian data for mileage and fuel use, and from other settings for external costs (emission and congestion-related damages). Their results can be summarized as follows. Imposing the optimal gasoline tax and removing fuel subsidies would lead to a reduction of 43 percent in gasoline use (corresponding to a 25 percent reduction in auto and microbus miles driven), with a net social benefit of around US$11 per capita. As the level of the tax would be as high as US$2.21 per gallon (a US$3.4 at the current price, given the fuel subsidy), the authors acknowledge the strong social impact such a policy would have, and recommend to consider also social and political determinants behind policy implementation.

The optimal auto mileage toll policy is associated with a 22 cent per vehicle mile, leading to a net benefit of US$4.3 per capita. It is to be noted that the tax level accounts not only for negative externalities (local and global pollution), but also for positive ones (decrease in pollution and congestion for microbuses). Such a policy would lead to a reduction in auto miles of about 27 percent, and would be equivalent to a fuel cost of U$4.2 per gallon. Interestingly, a suboptimal policy with a mileage toll of 5 cents instead of 22 cents would be interesting to consider, as it would lead to a net social benefit of US$3 per capita (70 percent of the net benefit under the optimal toll). As for microbuses, the authors estimate the optimal level of the mileage toll at 8 cents per vehicle mile, associated with an eight percent reduction in microbus miles and a 10 cent net benefit per capita. The low level of this tax is explained by the positive externality due to the diversion of passengers onto private cars (external costs being three times higher for cars in terms of passenger mile per vehicle), which more than offsets the negative components (congestion for microbuses, pollution, accidents).Finally, Parry and Timilsina (2010) find that optimal transit fares (rail and public bus) are not out of line compared with current ones, which justifies the fact that public transit is subsidized: transit fares are below average operating costs because externalities from other transportation modes are to be reduced.

Parry and Timilsina (2010) make strong assumptions about the diversion elasticities across transportation modes. In particular, they assume that 80 percent of the modal share of cars will be diverted to other modes following a gasoline tax, the new distribution across these modes being proportional to the initial one. For policy recommendations in particular, it is important to determine whether these assumptions are valid, as far as the behavior of Egyptian households is concerned. In the next section, we will construct a demand model for transportation modes at the household level, to estimate elasticities of substitution across transportation modes. This will allow us to provide more precise information on important components of the demand for transportation in Greater Cairo. Although the complete modeling from household decisions to ambient atmospheric pollution is well beyond the scope of thischapter, the next section will also propose an econometric ex post analysis of the impact of environmental policies, in the form of a panel-data model for atmospheric emission.

4. Evaluation of the Actual Egyptian Regulation

In this section, we evaluate the Egyptian regulation policy from several perspectives. First, we examine the policy choices, in terms of the nature of instruments selected, with reference to the literature on environmental policy performance. Second, we propose a way to improve information to support policy evaluation and design by addressing the issue of household choices regarding transportation modes. A demand system dedicated to urban transportation by households is estimated on individual data, and can be used in connection to the emission model, to predict the impact of a policy affecting transportation costs on the final ambient emission concentration. The advantage of this approach is that all model parameters are obtained from estimates using Egyptian data, and are not arbitrarily imposed nor transferred from other settings. Finally, we propose an empirical analysis of the relationship between motor vehicles and atmospheric pollution, using data from the air-quality monitoring stations described above (section 2.1). As some environmental policies undertaken by the Egyptian government directly impact the number of motor vehicles in Greater Cairo, this emission model can in principle be used to predict future levels of pollution.

4.1 The policy options

In order to design a policy agenda for these measures, economists rank them according to increasing marginal cost of emission reduction and the latter as a function of cumulative emission reductions (Sterner 2003). In a study on Mexico City, Eskeland (1994) reports a marginal cost below US$100 per ton for retrofitting to natural gas and Liquid Petroleum Gas (LPG), between US$100 and 600 for emission standards on minibuses, gasoline trucks, taxicabs (replacement) and passenger cars, and between US$1,100 and 2,600 per ton for fuel improvements. Retrofitting, inspection and maintenance measures are very effective because a large share of overall pollution is due to a smaller percentage of vehicle distribution, typically the oldest ones.

Eskeland (1994) suggests starting with the retrofitting of trucks and minibuses with LPG, then to an inspection and maintenance program for high-use vehicles (mass transport vehicles such as taxicabs, delivery vans, etc.) and moving gradually to private cars. Fuel improvement policies should be adopted last, with significant savings being possible if fuel taxes are imposed instead of an inspection program (25% more expensive in the case of Mexico City). In the case studied by Eskeland (1994), he suggests the use of two second-best instruments jointly to produce the best feasible policy mix: a fuel tax to reduce traffic intensity through a reduction in demand, and technical improvements to reduce emission rates (emissions per km).

In view of the procedure described above to rank policy options and determine what the best policy agenda would be, it must be said that the Egyptian government has addressed the problem of air pollution from motor vehicles in a way consistent with that suggested by Sterner (2003). This statement is supported by the recent policies that have been implemented in the last four or five years, that include old vehicle scrapping and recycling, inspection of mass transit vehicles, reduction in fuel subsidies, ban on motorcycles and on renewing licenses for old vehicles. Together with these short-run regulatory and economic measures, the program for extending the GC public transportation system is also consistent with the need to provide commuters, and private car owners in general, with alternative transportation modes.

Nevertheless, the implementation of plans for GC has been slower than envisioned and traffic has increased more than originally expected. For instance, JICA (2003) projected a reduction in travel speed from 19 km/h to 12 km/h by 2020 in the worst case scenario. The most recent estimates indicate that the travel speed had already fallen to around 12 km/h in 2005, notably due to the increase in car ownership associated with higher income growth and urbanization. This is supported by government officials with anecdotal evidence.

4.2 A choice model for transportation modes

To evaluate environmental policies aimed at modifying drivers' behavior with incentive instruments, it is important to have an accurate representation of their preferences regarding transportation modes: the ones impacted by the policy, and the modes which can be considered substitutes. For example, a policy targeting the cost of using private cars through a gasoline tax or a policy of cheaper mass transit will have an indirect impact, through substitution effects, on other transportation modes. We present here the estimation of the elasticities of transportation modes for the GC region. Most transportation models are estimated on individual data with the use of a discrete-choice model (multinomial, nested or mixed logit) dedicated to exclusive choices. Given cost and time variables for a specified travel route, probabilities of using alternative modes are typically estimated from travel surveys. This does not mean that substitution elasticities across transportation models cannot be estimated, since the probability of a change in a particular mode following a change in the unit cost of a transportation mode is easily computed from such models.

The data we use was collected from IDSC (2008) for the year 2007, and does not contain information on particular travel routes. Instead, the data contains household-level information on transportation cost per mode over a one-week period, hence allowing for multiple-mode analysis to be conducted. As a consequence, we do not consider discrete-choice modeling to infer transportation behavior; rather we adopt a demand-analysis approach. More precisely, the fact that total expenditure per transportation mode is available allows us to represent transportation decisions with the tools of applied consumer demand. In such a framework, we do not model the probability for a household to select a particular transportation mode for a particular route, but we model the level of transportation demand for each mode, as a function of all transportation unit costs.

Consider M possible transportation modes (car, micro bus, taxi, etc.), with unit cost (per trip) p_j and demand (number of trips) denoted by q_j, $j = 1, 2, ..., M$. Since detailed information on individual trips is not available, the unit cost of trips is some average over the usual trips taken by the households. Moreover, the demand for transportation associated with a particular transportation mode can represent a given number of homogeneous-distance trips, or the total distance travelled by an individual over the total number of trips. The total expenditure on transportation is represented by $R = \sum_{k=1}^{M} p_k q_k$, and transportation expenditure shares are computed by $w_j = p_j q_j / R, \; j = 1, 2, ..., M$. We further make the assumption that the budget on transportation, *R*, is separable from the total household budget. In other words, decisions on transportation choices are not affected by the prices of other budget items. This is of course a critical assumption with regards to car ownership and related expenditures, and it implies a particular assumption on consumer preferences, namely, the difficulty to separate the household's utility function into transportation choices and other goods. In particular, when the cost of cars (or car repairs) increases, it is expected to have a major impact on the decision to adopt a public transportation mode. Additionally, the cost of fuel is also likely to affect transportation modes, even when private and public modes using gas are considered. We will discuss this point later.

A popular way of representing a demand system for multiple goods is the Almost Ideal Demand System (AIDS) model of Deaton and Muellbauer (1980). Assuming a Piglog representation of preferences (through a total expenditure function), a linear function of expenditure shares is obtained, as a function of the log of the costs of transportation modes and normalized total expenditure. The Linear Approximated AIDS model (LA-AIDS) reads:

$$w_j = \alpha_j + \sum_{k=1}^{M} \alpha_{jk} \log p_k + \beta_j \log\left(\frac{R}{P}\right), \quad \forall j = 1, 2, ..., M,$$

where $P = \sum_{k=1}^{M} w_k \log p_k$ is the Stone price index. Homogeneity, adding-up and symmetry conditions are easily imposed on the system of expenditure shares, as linear parametric restrictions:

$$\sum_{k=1}^{M} \alpha_{jk} = 0, \; \forall j = 1, 2, ..., M, \sum_{k=1}^{M} \alpha_k = 1, \; \sum_{k=1}^{M} \beta_k = 0.$$

Compensated (Hicksian) own- and cross-price elasticities are computed from parameter estimates as follows:

$$\varepsilon_{jj} = -1 + \frac{\alpha_{jj}}{w_j} - \beta_j \text{ (own-price elasticity),}$$

$$\varepsilon_{jk} = \frac{\alpha_{jj}}{w_j} - \beta_j \frac{w_k}{w_j} \text{ (cross-price elasticity).}$$

Table 3 presents descriptive statistics for households not having a private car and for the full sample, on cost per trip, the number of trips per week, and the transportation cost shares. We consider public buses, AC buses, microbuses, taxicabs and underground as major transportation modes, but the sample does not contain information on cost and travel frequency associated with private cars. Finally, less frequently used modes such as tram and tuk-tuk are grouped in the "others" category. As table 3 illustrates, the distribution of expenditure share on public transportation is not significantly different between the full sample and the sub-sample of households not owing cars. Moreover, the total transportation cost is about LE7 more for the former group. Furthermore, the most frequently used transport mode is the microbus as represented by the number of trips per week or in terms of its expenditure share.

A particular aspect of the analysis to note is the fact that most households do not have positive expenditures on all transportation modes over the observation period. This is the selection issue, underlying determinants of the choice of transportation modes being unobserved and being possibly correlated with the unobserved demand component. To correct for a possible selection bias, techniques based on the Tobit approach are well known in a univariate setting. In the case of multivariate selection, however, we have to adapt the Tobit procedure to account for the fact that unobserved determinants of selection may be related to more than one selection probability. Consider an unobserved component of preferences for transportation modes, specific to households and unobserved to the analyst. Such a component may for instance lead a particular household to systematically prefer taxis or private car to other transportation modes. Selection of positive modes will be observed (car, taxi) and the probability to observe public transportation modes such as bus or underground is likely to be correlated across such modes. If the unobserved component underlying the selection decision of transportation modes is correlated with the demand (the number of trips) for transportation, then a multiple selection problem will occur. There are several econometric procedures for dealing with the multivariate selection issue. Many rely on the specification of a structural model, along the lines of Lee and Pitt (1986), and imply computer-intensive estimation procedures (simulation-based inference). We adopt here the simpler approach suggested by Lacroix and Thomas (2011) (see Maddala 1983), which extends the Tobit framework to multivariate selection. In practice, we first estimate the probability of selection for each transportation mode with Probit. We then compute the Mills' ratios and add them to each of the budget shares in the AIDS system. We finally multiply each share equation by the selection probability to obtain the non-conditional expectation of the share, where the series of Mills' ratios control for multivariate selection.

Formally, define d_j^* as the continuous latent variable representing selection of transportation mode, with the associated observed dummy variable $d_j = 1$ if $d_j^* > 0$ and 0 otherwise. d_j^* may represent for example the profitability of the transportation mode, which will be positive whenever the associated share is positive. The expectation of the transportation share is

$$E\left(w_j\right) = \Phi_j \times \left[\alpha_j + \sum_{k=1}^{M} \alpha_{jk} \log p_k + \beta_j \log\left(\frac{R}{P}\right) + \sum_{k=1}^{M} \lambda_k \frac{\phi_k}{\Phi_k}\right],$$

where $\Phi_j = \Pr(d_j^* > 0)$ with associated density function ϕ_j, and λ_k is the Mills' ratio corresponding to selection equation *k*. The equation above can be estimated on the full sample containing censored and positive expenditure shares, provided that prior estimates are available for $\Phi_j = \Pr(d_j^* > 0)$. The latter are typically estimated by Probit, using unit cost and household characteristics (age group, education) as explanatory variables for the selection of transportation modes.

Tables 4 and 5 present the (compensated) elasticity estimates for the subsample of households which do not own a private car and for the full sample, respectively. Own-price elasticities are all close to -1 and significant in the subsample of no-car owners, while they exhibit more heterogeneity and are not always significant in the full sample. For the latter, significant own-price elasticities range from -0.59 to -1.44, and those of the AC bus and other modes are not significant. The highest own-price elasticities in both samples are for public buses, AC buses and microbuses modes, while most cross-price elasticities are not significant. Notable exceptions are the following:

- In the sample of no-car owners, public buses have other public transportation modes (other bus modes, tube) as substitutes and taxi as a complement;
- AC buses have taxis as a complementary transportation mode; and
- Microbuses have taxis as a complement and tube as a substitute.

It turns out that most public transportation modes are substitutes, and have taxicabs as a complementary mode, probably because many households consider jointly several transportation means. Moreover, the network of public transportation is not well developed to reach all households at a walking distance, hence creating the need to combine public transportation and taxicab modes.

In the full sample (Table 5), the same pattern is also found, with some exceptions (public buses now have the tube as a complement) and an even smaller number of significant cross-price elasticities. The AIDS model fits the data reasonably well, in particular for taxi and microbus transportation modes. However, our dataset does not contain precise information on typical trips which could involve multimodal behavior. Our empirical analysis is at the household level and addresses the demand for transportation as a single commodity or service. Nevertheless, the differences in price elasticities between no-car owners and the full sample can provide interesting indications regarding the modal shifts if car use is discouraged. In this case, car owners would tend to act as no-car owners for their trips within GC, and they would be less sensitive to the cost of public transport (public buses in particular). Moreover, no-car owners are more sensitive to the cost of taxicabs, according to our estimates. It may then be expected that a policy aimed at discouraging the use of private cars will favor public transportation (especially public buses) and not so much taxicabs, as the own-price elasticity of taxicabs is higher and the one of public transportation is lower for no-car owners.

The micro-econometric analysis presented here is not free of limitations, many originating from the incomplete data available. In particular, the lack of data on average number of car trips is a serious limitation, which restricts a direct comparison between empirical results presented in this chapter and estimates used for the simulation exercise of Parry and Timilsina (2010). Our results however reveal that the assumption made by Parry and Timilsina (2010) about the new distribution, following a change in gasoline price, across transportation modes other than cars (assumed proportional to the initial one) is questionable, as a change in the gasoline price will presumably modify other unit transportation prices, and will have a less straightforward impact on transportation modes.

4.3 An emission model for Greater Cairo

Anex post evaluation of the performance of the policies implemented in Greater Cairo seems possible, as some of these policies have been in effect for some years now. As discussed in section 2, data collection from air quality monitoring systems allows for a quantitative assessment of the policies. A difficulty remains, however, as to control the inevitable lags in the relationship between policy implementation, participation from targeted population, and the final environmental outcome. Moreover, some policies have been initiated almost simultaneously, so that identifying individual policy performance might be difficult in practice.

We present in this section an attempt to conduct an ex post evaluation of the Egyptian policies regarding atmospheric pollution. As noted before, most policies have been initiated in 2008, for which we observe a reduction in the concentration level of PM10.The objective is to test whether the post-implementation period is truly associated with a reduction in PM10 concentration, when controlling for changes in road traffic as the major source of pollution, and other seasonal effects. We construct the variable POLICY, which takes the value 1 for years 2007 and 2008 (implementation of new regulations), and 0 otherwise. Because we do not have information on actual traffic in GC (e.g., passenger miles over time), changes in traffic density is proxied by the number of registered motor vehicles over the 2002-2008 period. Registered motor vehicles are distributed across public and private buses, private cars and trucks. Before 2007, the official number of registered motor vehicles other than buses and private cars was not available. Therefore, we restrict the number of motor vehicles to private cars, minibuses and microbuses only, for which we have data over the entire period. Since the period is much shorter than the average life of trucks, we hope that this restriction does not significantly affect estimation.

We also account for the influence of peak hours on the average daily PM10 concentration level, by constructing the dummy variable PEAK taking value 1 if hours correspond to the peak period, defined here as between 7AM and 10AM, and between 5PM and 8PM, and 0 otherwise. The emission model for PM10 is estimated by fixed-effects with a log-log specification, the quality-monitoring station being the cross-sectional unit, and with POLICY, number of registered motor vehicles and peak-hour as explanatory variables. We also introduce month dummies (January is the reference month) to pick up seasonal effects in emissions. As the data on vehicles is not available for the year 2001, this year is dropped from the sample used for estimation.

The emission model to be estimated is the following:

$$\log(PM_{it}) = \beta \log(VEHICLES) + \gamma POLICY + \delta PEAK + \sum_{m=2}^{M} \alpha_m 1(MONTH_t = m) + \alpha_i + \varepsilon_{it},$$

where i is the index of the monitoring station and t the time index, $1(MONTH_t=m)$ denotes a monthly dummy (from February to December), and $\alpha_i$andε_{it} are the station fixed effect and the i.i.d. error term respectively.

Estimation results are presented in Table 6. The variable POLICY is significant with a negative coefficient of -0.031. This means that the post-implementation period (2007-) is associated with a reduction of about three percent in PM10 concentration, when controlling for the change in the number of motor vehicles per year. The number of registered motor vehicles is significant and positive, with a value around 0.41, indicating that one percent increase in the number of motor vehicles would lead to an increase in PM10 concentration by around 0.4 percent. Other control variables such as PEAK are significant at the 5 percent level: the elasticity of PM10 is about eight percent with respect to peak hours compared to lower congestion periods.

In this empirical application it is necessary to regard the dummy POLICY with a bit of caution. This variable is likely to pick up any unobservable and potentially confounding variation systematic to the years 2007 and 2008, so that our results should be taken with caution. By including in the model the number of motor vehicles, we are partly controlling for observed determinants of ambient pollution, but other (unobserved) factors may also explain the trend in atmospheric pollution after the year 2007.

It is possible, in principle, to relate the estimated model of emissions with the previous exercise devoted to transportation demand of Egyptian households in Greater Cairo.

However, as data on car trips is not available, we can only conjecture the expected impact of a change in the unit cost of public transportation modes on the same modes. Furthermore, the demand model is based on demand for trips whereas the emission model depends on the actual number of motor vehicles in Greater Cairo. The following assumption is therefore needed: that a change in the number of trips for a particular motor vehicle will have the same effect (on ambient concentration level of PM10) as an equivalent proportional reduction in the number of these vehicles. To fix ideas on a possible use of both models, consider the following example. Assume a policy aims at diverting households from taxi cabs to other public transportation modes (in particular, tube and public bus) by raising the cost of taxi trips by 10 percent. From elasticities in table 5, a 10 percent increase in the cost of taxi will lead to a decrease of six percent in their use, and 0.8 percent increase in bus use. Since the proportion of taxi cabs in the total stock of motor vehicles is about five percent (see section 2.1), we should expect at most a reduction in emissions of about0.06x 0.05 x 0.41 = 0.12 percent if households do not divert to private cars or other motor vehicles.

5. Policy Recommendations

A first policy recommendation is to explore alternative measures that could be tested for environmental performance and cost-effectiveness. One potential option is to consider pricing congestion that can cause population to spread from larger to smaller cities reducing total congestion. Such pricing can be implemented by introducing a congestion charge or a fuel tax (or a reduction in the subsidy in fuel expenditures), so that more funds can be devoted to subsidies for cleaner car vehicles and enhancing public transportation network.

Congestion charges have been implemented in Singapore, London and various cities of Norway and the United States. Interestingly, urban roads are often considered a public good (no exclusion) but it is only an imperfect one because of rivalry (as demonstrated by congestion). A congestion charge would then try to restore the public-good nature of urban roads by reducing the degree of rivalry among users. Systems of congestion charging can include special dispositions such as charging only motor vehicles with less than two passengers as in Singapore. The interesting aspect of congestion charging is that it generates a significant amount of revenue with moderate management cost, while allowing the policy to target specific areas in which congestion (and presumably pollution) is more severe. Indeed, compared to a fuel tax which applies to all drivers regardless of the period of the week/day and the region/area, the congestion tax aims at modifying the traffic paths within a delimited area. This obviously implies that alternative routes for motor vehicles and readily available public transportation systems are in place for transport modal change.

A good example is the construction of a ring expressway which would divert traffic from the city center to the suburbs, at the cost of additional travel time. It is, therefore, not surprising that most examples of congestion charges are found in cities where alternative routes or public transportation modes are relevant substitutes. In terms of impacts on environmental quality, congestion charges tend to have often better results than other tax-based policies, especially congestion charges based on distance travelled. On the downside, however, congestion charge policies are often criticized for being regressive because of their disproportionate impact on low-income households, unless revenues generated by the tax are invested in the public transportation system (Arnottet al.1994). Unfortunately, the distributional impact of congestion charges is related to the location of commuters and motor vehicle users in general, so that a precise assessment of social welfare implications of such a policy would be impossible without adequate survey data collection and treatment (Timilsina and Dulal 2008). An intermediate option is to consider a moderate congestion tax based on specific peak periods and delimited areas, which would not unduly penalize commuters but would provide infrequent travelers with incentives to modify their travel schedule to avoid peak hours.

A fuel tax system or equivalently a reduction/elimination of fuel subsidies, would not target the most significant areas of Greater Cairo in terms of traffic congestion. An interesting purpose, however, is to provide revenue to the government to boost the public transportation plan and the urban planning projects, with a possible indirect effect of providing incentives for carpooling. Since the public's acceptance of such a policy is unlikely, imposing a fuel tax for environmental objectives only is not recommended.

Since vehicle taxes charged according to the distance travelled have been seen to be superior in terms of emission reduction, a simple possibility is to associate the car registration (renewal or for a new vehicle) procedure with a technical inspection on compliance with emission standards and vehicle age, and to add a measurement of distance travelled over the past year. This last criterion is unfortunately one of the easiest to modify fraudulently, and alternative measurement devices should be considered.

Considering subsidies for vehicle replacement by cleaner motor vehicles, many studies provide evidence that a subsidy policy is necessary to promote participation in vehicle exchange programs. However, most empirical studies are on hybrid or electric vehicles the costs of which are too high to be considered as alternatives by the majority of present households and taxi drivers in Egypt. Cheaper alternatives are then technical modifications on the engine and the vehicle to switch to lead-free fuel, compressed natural gas or LPG.

The second policy recommendation would be—following the exploration of alternative policies described above—to base the coming programs of measures on a consistent and more stable budget plan for a reasonable period of time. This would provide more credibility in the form of a commitment from the government to pursue the effort already engaged. At the same time, the government should conduct a general welfare assessment exercise which would account, not only for motor vehicle regulation to control air pollution, but also for subsidy policies targeting households. This is particularly important as far as fuel subsidies are concerned, since an alternative possible policy would involve eliminating energy subsidies and shifting such budget funds to food items or other commodities.

6. Conclusion

This paper addresses the problem of atmospheric pollution generated from traffic in Greater Cairo. We start by conducting a transport mode choice analysis using 2007 data containing household-level information on transportation cost per mode over a one-week period. The AIDS model is applied to represent the demand system for multiple goods as represented in various transportation modes such as cars, buses, and taxicabs. The results suggest that most transportation modes are complementary, perhaps due to the fact that a typical trip may involve multimodal behavior.

An assessment of existing policies to curb down atmospheric pollution sources from motor vehicles in GC is performed. In order to compare average daily PM10 concentration level both before and after the regulation, a fixed effect model is estimated for the period 2002-2008, accounting for the number of registered motor vehicles, seasonality in emissions and peak hours. The results reveal that the policy agenda addressed the problem of air pollution from motor vehicles in a way that a significant albeit limited degree of emission reduction is observed. However, the implementation of some measures remain slower than the rapid increase of traffic. Better economic instruments for controlling nonpoint source pollution are advocated as well. This should be set as top priority to the EEAA since the average speed has already dropped to 8 km per hour in 2011. It is anticipated that such policies will control atmospheric pollution as well as congestion.

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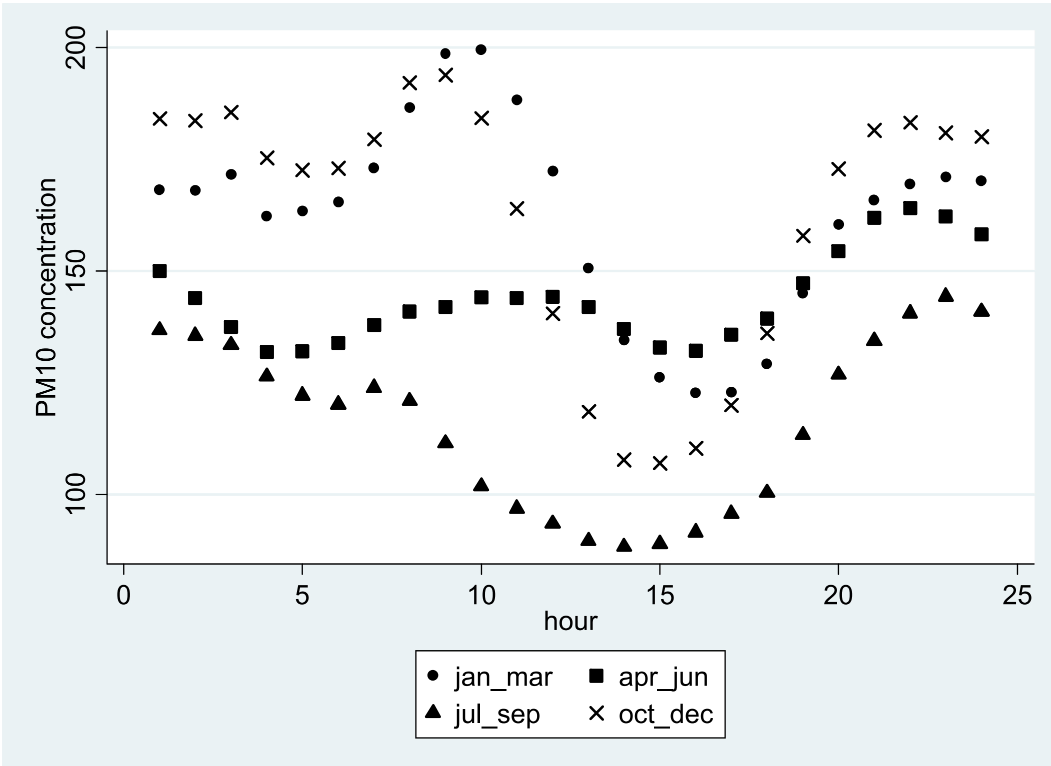
Figure 1: Hourly Average Concentration of Suspended Particulates (PM10) (in µg/m^3), by Season, 2001-2008



Source: Authors' compilation from EEAA data.

Table 1: Annual Average Concentration of Suspended Particulates (PM10) (in Mg/M^3), in Selected Air-Quality Monitoring Stations, Greater Cairo, 2001-2008

Quality monitoring station	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Abbasseyia	172.28	183.46	209.32	153.63	111.02	131.49	121.73	136.06	152.17
Fum ElKhalige	159.82	126.60	174.8	171.86	120.48	170.22	153.87	125.88	149.00
Heliopolis					117.12	123.78	179.58	105.95	130.92
Helwan							170.61	145.05	154.37
Kaha							127.78	237.35	164.49
Kolaly	137.80	123.35	213.80	157.95	124.50	165.33	179.58	148.33	156.69
Mohandessin					142.31	123.30	127.97	154.75	136.13
Shebeen ElKom							185.32	174.63	180.07
Shoubra								259.74	259.74
Tebbin	197.17	109.70	141.73	106.23	96.65	166.93	164.87	148.04	141.29
Tahrir							122.99	126.74	124.79
Zeraah							123.44	109.97	117.39
All stations	166.31	136.08	184.48	147.89	113.81	143.02	145.98	144.07	146.23

Source: Authors' calculation based on data provided by the EEAA.

Table 2: Traffic Control Measures and Economic Instruments to Reduce Automobile Pollution

Category of measure	Program	Notes
Traffic Control Measures	1. Improvement of public transit	
	2. Improve traffic flow to restricting trailers and heavy trucks movements to off-peak periods	Interesting for reducing extreme pollutant concentration during peak traffic periods.
	3. Reduce idling periods for motor vehicles	Costly to implement, requires alternative roads.
	4. Encourage non-fuel vehicles for individuals	Must account for safety considerations.
	5. Encourage voluntary withdrawal and restrict purchase of old vehicles	Efficient way of reducing pollution, may face resistance on economic grounds.
	6. Retro-fitting old vehicles with emission-reducing devices	Must consider economic and technical feasibility.
	7. Empower traffic police to control and sanction poorly-maintained motor vehicles	Long overdue.
Economic instruments	1. Introduce emission tax for all categories of vehicles, based on: a) annual distance covered b) age of vehicle c) fuel type	
	2. Reduce or remove subsidies on petroleum products	Increase government revenue (unless tax receipts used for other purposes, e.g., food subsidies). May reduce single-occupant vehicle uses.
	3. Increase vehicle registration and parking fees	
Others	1. Programs of effective urban planning	
	2. Education and voluntary approaches	
	3. Better communication facilities (video, telephone, Internet)	

Source: Adapted from Orubu (2004).

Table 3: Unit Cost, Expenditure Shares and Total Transportation Cost

	Full sample			No-car owners		
	Cost share	**Unit cost (LE per trip)**	**Trips per week**	**Cost share**	**Unit cost (LE per trip)**	**Trips per week**
Public bus	0.1692	2.1820	1.45	0.1887	2.3495	1.73
AC bus	0.1799	2.4281	1.43	0.1767	2.4307	1.52
Microbus	0.3097	2.6409	1.88	0.3141	2.6732	2.09
Taxicabs	0.1543	7.8037	0.68	0.1349	7.7362	0.62
Underground	0.1473	2.1735	1.04	0.1434	2.1749	1.10
Others	0.0394	9.4693	0.10	0.0420	7.1938	0.12
Total transportation cost (LE per week)		101.85			95.09	

Source: Authors' calculations

Table 4: Compensated Price Elasticities of Transportation Modes (no-car owners)

	Price					
Mode	**Public Bus**	**AC Bus**	**Micro-bus**	**Taxi**	**Tube**	**Others**
Public Bus	-0.8430***	0.0558**	0.0714*	-0.3508***	0.0711*	0.0266
	(-33.13)	(2.09)	(1.77)	(-2.91)	(1.80)	(0.90)
AC Bus	-0.1161	-1.0824***	-0.1747	0.5869**	-0.1182	-0.0009
	(-1.55)	(-47.02)	(-1.54)	(2.32)	(-1.54)	(-0.02)
Microbus	-0.6033	-0.0580	-1.0292***	0.2335**	-0.0644*	0.0027
	(-1.47)	(-1.69)	(-42.60)	(2.07)	(-1.69)	(0.10)
Taxicabs	0.0285***	-0.0449	0.0099	-0.9844***	-0.0009	0.0158***
	(4.56)	(-0.85)	(1.57)	(-31.24)	(0.0061)	(2.67)
Tube	0.0323	0.0187	0.0158	-0.0585	-0.9774***	0.0380***
	(1.10)	(0.92)	(0.53)	(-0.58)	(-39.55)	(3.05)
Others	0.3729	0.3001	0.4380	-1.5350	0.4221	-0.8935**-(-
	(0.67)	(0.71)	(0.66)	(-0.70)	(0.62)	15.59)
R^2 of AIDS share equation	0.2938	0.3097	0.3229	0.6685	0.1518	0.1138

Notes: 276 observations. Student *t*-statistics are in parentheses. Estimates computed from the AIDS demand system with correction for multiple selection.*, ** and *** denote parameter significance at the 10, 5 and 1 percent level, respectively.

Table 5: Compensated Price Elasticities of Transportation Modes (all households)

Mode	**Public Bus**	**AC Bus**	**Micro-bus**	**Taxi**	**Tube**	**Others**
Public Bus	-1.3122***	-0.0132	0.0284	0.0836**	-0.0467**	0.0249
	(-18.97)	(-0.88)	(1.01)	(2.51)	(-2.20)	(0.89)
AC Bus	0.9626	-0.5930	-0.4528	-1.1815	-0.2190	0.2580
	(0.58)	(-0.56)	(-0.55)	(-0.53)	(-0.38)	(0.33)
Microbus	-0.2281	0.2454	-1.4433***	0.3956	0.1426	0.1433
	(-0.91)	(1.04)	(-6.11)	(1.26)	(0.87)	(0.64)
Taxi	-0.1130**	-0.0238	-0.0240	-0.5982***	0.0410	-0.1348***
	(-2.46)	(-1.09)	(-0.69)	(-4.84)	(1.46)	(-4.67)
Tube	-0.0228	-0.0558	-0.3798	0.7744	-1.0932***	-0.0750
	(-0.10)	(-0.42)	(-0.63)	(0.57)	(-3.03)	(-0.40)
Others	-0.6551	0.2572	-0.2969	-0.3176	-0.0401	-0.3039
	(-0.71)	(0.62)	(-0.74)	(-0.60)	(-0.32)	(-0.29)
R^2 of AIDS share equation	0.3089	0.2953	0.3452	0.6611	0.1224	0.0715

Notes: 377 observations.*t*-statistics are in parentheses. Estimates computed from the AIDS demand system with correction for multiple selection. *, ** and *** denote parameter significance at the 10, 5 and 1 percent level, respectively.

Table 6: Fixed-effect Parameter Estimates of the PM10 Equation (2002-2008)

	Log-log model	
Variable	**Estimate**	***t*-statistic**
Constant	-1.3039	-2.45
POLICY	-0.0314	-6.07
log VEHICLES	0.4146	11.05
PEAK	0.0883	24.11
January	Reference	-
February	0.0458	5.72
March	0.0896	11.54
April	0.0226	2.87
May	0.0676	8.69
June	-0.1247	-15.27
July	-0.1221	-15.46
August	-0.1735	-21.77
September	-0.1175	-15.26
October	0.2395	31.66
November	0.2149	28.62
December	0.2051	25.79
Observations	289,321	
F-test (alpha=0)	516.79	(p-value) 0.0000
Sigma_Alpha	0.1257	
Sigma_Epsilon	0.8562	
R^2 Between	0.1062	
R^2 Within	0.0279	

Notes: *, ** and *** denote parameter significance at the 10, 5 and 1 percent level, respectively. Sigma_Alpha and Sigma_Epsilon are respectively the variance components of the cross-sectional and the i.i.d. random terms. F-test is the Fisher test for the presence of heterogeneous intercept terms.

Appendix

Table A1: Hourly average concentration of suspended particulates (PM10) (in µg/m^3),by season, Greater Cairo, 2001-2008.

Hour	January-March	April-June	July-September	October-December	Total
12PM-1AM	168.25	149.99	136.74	184.02	160.48
1AM-2AM	168.03	143.91	135.57	183.63	158.48
2AM-3AM	171.71	137.52	133.43	185.50	157.89
3AM-4AM	162.25	131.87	126.41	175.35	149.74
4AM-5AM	163.43	132.05	122.19	172.55	148.25
5AM-6AM	165.44	133.95	120.14	173.07	148.79
6AM-7AM	173.15	137.93	123.89	179.47	154.31
7AM-8AM	186.67	141.01	120.99	192.11	161.06
8AM-9AM	198.70	141.89	111.50	193.83	162.30
9AM-10AM	199.50	144.16	101.87	184.22	158.12
10AM-11AM	188.39	143.92	96.871	163.89	148.74
11AM-12AM	172.34	144.23	93.49	140.58	137.70
12AM-1PM	150.59	141.99	89.56	118.56	124.83
1PM-2PM	134.52	137.00	88.27	107.74	116.49
2PM-3PM	126.15	132.87	88.94	106.95	113.35
3PM-4PM	122.82	132.17	91.56	110.38	113.91
4PM-5PM	122.89	135.82	95.72	120.00	118.43
5PM-6PM	129.16	139.41	100.40	136.07	126.36
6PM-7PM	145.06	147.23	113.30	157.87	141.16
7PM-8PM	160.49	154.48	126.84	172.85	154.04
8PM-9PM	165.94	161.92	134.42	181.57	161.39
9PM-10PM	169.48	164.17	140.57	183.19	164.76
10PM-11PM	171.12	162.29	144.30	180.95	165.03
11PM-12PM	170.23	158.25	140.98	180.01	162.82
Total	161.95	143.83	115.86	161.92	146.23

Source: Authors' compilation from EEAA data.