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Detox Development: Repurposing Environmentally Harmful Subsidies

Background Paper

Fossil Fuel Prices and Air Pollution

Evidence from a Panel of 133 Countries

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Abstract

Fossil fuel combustion is a major contributor to urban air pollution, which in turn can lead to negative health outcomes. While the relationship between fuel prices and consumption has been extensively documented, the knock-on impact on air quality is less studied. Detailed knowledge on the price-pollution channel is valuable in designing effective pollution reduction measures. This paper analyzes the impact of gasoline, diesel, and coal prices on air pollution in 133 countries over a 19-year period. The dataset combines prices, consumption, country-specific variables, and annual average fine particulate matter concentrations in each country's capital city. Using the common correlated effects estimator, the analysis finds a robust negative relationship between gasoline and diesel prices and particle concentrations. A US$1 increase in the average annual retail price of these common transport fuels is associated with at least a 22.2 microgram per cubic meter decrease in annual average fine particulate matter concentrations. In contrast, there is no significant effect for coal, which is often used in power generation and industrial applications, making it less responsive to short-term price variations. Overall, the results are in line with earlier studies, as price increases are correlated with improved urban air quality for transport fuels.

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Fossil Fuel Prices and Air Pollution: Evidence from a Panel of 133 Countries

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1. Introduction and context

Excessive exposure to air pollutants can have severe negative health impacts and is a leading cause of death (WHO 2021), and emissions from fossil fuels burned by vehicles and for domestic use are known to substantially contribute to urban air pollution (Andrade et al. 2010; Parrish et al. 2009; Zhang and Smith 2007). As a result, many cities adopt low-emission zones, clean-burning fuels, and other measures to combat adverse effects on health and well-being. But although such policies have been found to be effective, they can incur substantial upfront costs for consumers and require enforcement (Zhai and Wolff 2021; Jones et al. 2012). In his seminal work, *The Economics of Welfare,* Arthur C. Pigou (1920) introduced an alternative mechanism applicable to anthropogenic emissions, proposing the use of taxes—and thus price incentives—to curb activities that cause negative externalities to a socially optimal level.

The relationship between fuel prices and consumption has been studied extensively in economic research and one would expect price changes to have follow-up effects on air quality. Although the exact magnitude of impact depends on price elasticity, lower fuel prices result in higher consumption, which, intuitively, should increase levels of anthropogenic fine particulate matter (PM2.5) pollution. This paper expands on available research on the price-pollution channel—which mostly focuses on city- and state-level analysis—by looking at the global relationship between fuel prices and consumption. Thus, our main contribution to the literature is an investigation into whether higher fossil fuel prices are tied to lower urban pollution levels globally.

To properly examine this notion, we estimate the relationship between PM2.5 concentrations, fossil fuel prices, fuel consumption, and country-specific variables using the Common Correlated Effects (CCE) estimator by Pesaran (2006) and a novel panel dataset that spans 133 countries over 20 years. Our findings suggest that, at the global level, transport fuel prices are significantly negatively correlated with air quality. Coefficient estimates for gasoline and diesel show a 22.2- and 31.1-microgram per cubic meter (μg/m^3) reduction in PM2.5 concentration for each US$1 increase in price, respectively. Coal prices, on the other hand, seem to have no significant effect. We discuss several reasons why the relationship between fuel price and air pollution may not be as pronounced as between price and consumption, including technological modernization, dedicated pollution control measures such as air filters, regulation, and timescales for effects to materialize.

The remainder of this study is structured as follows. Section 2 provides an overview of existing literature on air pollution and fossil fuel prices. Section 3 summarizes the data sources and analytical methods used (including selection of the CCE estimator). Section 4 presents the results, and section 5 discusses policy implications.

2. Literature review

Scientific research on air pollution focuses on the pollutants that are most toxic to human health, such as PM2.5, ozone, nitrogen dioxide, carbon monoxide, and sulfur dioxide, which have all been documented to lead to significant health issues, given prolonged exposure. Some well-established outcomes include cardiovascular illness, stroke, and cancer (Kampa and Castanas 2008). The WHO estimates that in 2016 alone, indoor and outdoor pollution led to 7 million deaths, mostly in the world's developing regions (WHO 2018). Air pollution is dangerous at a global scale, as over 90 percent of the world's population lives in areas with PM2.5 concentrations above the 2005 WHO air quality guideline recommendation of an annual average level of 10 $\mu g/m^3$ (WHO 2021).

Many air pollutants are released and formed through the combustion of fossil fuels (Perera 2017), which is pervasive in daily life. In the United States, 92 percent of gasoline consumption is accounted for by light-duty vehicles (EIA 2022); and the European Energy Agency considers road transport a significant contributor to PM2.5 pollution in European Union (EU) member states (EEA 2021). Andrade et al. (2012) estimate that at least 40 percent of urban PM2.5 concentration in six major Brazilian cities comes from vehicle emissions, while Abu-Allaban et al. (2007) find that motor vehicles are responsible for 20–76 percent of ambient PM2.5 concentration in the United States. Thus, reducing traffic or vehicle pollution intensity would be one pathway to substantial public health benefits (Laumbach and Kipen 2012). While there are many ways to influence emissions and traffic volume—including establishing low-emission zones or building subway systems[1]—employing price changes to incentivize a shift in consumer behavior is a popular instrument among economists.

2.1. Prices drive gasoline consumption

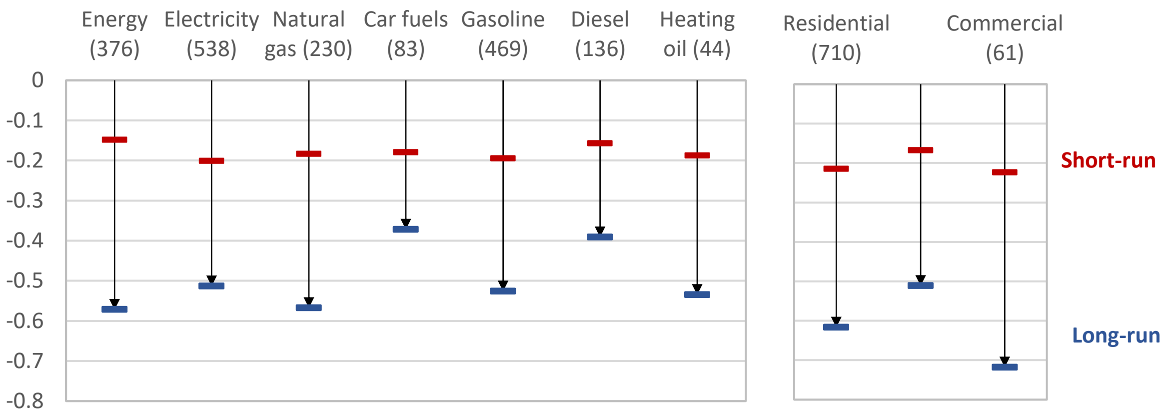
The price of fossil fuels is crucial in setting incentives for consumption and associated pollution. However, the effectiveness of price-based policies such as subsidy reform in reducing air pollution depends on the responsiveness of consumption choices to prices and vice versa.

It is a fundamental principle of economics that lowering the price of a good tends to increase demand for it. The extent to which consumption choices are sensitive to price changes can be empirically measured in the form of *price elasticities of demand*. In the context of air pollution, price elasticities are a crucial component in understanding the underlying forces that drive pollution outcomes. For example, lower gasoline prices would result in higher consumption, which, intuitively, we would expect to increase levels of PM2.5 pollution.

[1] See Zhai and Wolff (2021) and Jones et al. (2012) for discussions on the efficacy of low-emission zones and Gendron-Carrier et al. (2022) for analysis on the impact of a subway system on air pollution.

Confirming this intuition, price elasticities of demand have widely been shown to be negative for fossil fuels; that is, higher prices reduce consumption (Dahl 2012; Labandeira et al. 2017). Where elasticities are estimated to be positive, data limitations, time lags, and measurement errors play an important role.[2] While the negative relationship is well established, there is ample heterogeneity in the magnitude of the effect between countries and across fuel types. Using results from Labandeira et al. (2017), we visualize these differences in figure 1, summarizing average elasticity estimates for different energy types and groupings.

Figure 1. Average price elasticities of energy demand



Source: Based on data from Labandeira et al. (2017)
Notes: Energy refers to a pooled basket of different energy goods. *Car fuels* refer to a pooled basket of vehicle fuels. Numbers in parentheses indicate the number of observations (studies) in the literature on which these averages are based.

Across different energy types and users, a 10 percent increase in the unit price of energy results in a 2 percent short-run reduction in consumption. This is relatively low, reflecting that consumers adjust their choices, but are likely to face short-run constraints in doing so. For example, they may try to avoid driving for leisure trips, but cannot stop commuting to work.

But in the long run, consumption choices are more responsive to price changes. Average long-run price elasticity estimates in the literature suggest that a sustained 10 percent increase in energy prices leads to a 4–7 percent drop in consumption, depending on fuel type and user (figure 1). It is important to note, however, that demand remains inelastic, and that the response to price changes is sluggish. A relatively more elastic demand in the long versus short run implies that, given time to adjust, consumers will shift away from fossil fuels (Sterner 2007). For example, in the case of transport fuels, consumers could choose to replace fuel-inefficient vehicles or reduce travel (for example, by moving

[2] For example, when diesel pump prices drop at the beginning of the week and then rise more than they fell, the weekly average diesel price may show a small increase overall, as people may have rushed to fill up their vehicles at the beginning of the week to lock in the low price. Such effects may result in positive elasticities under special circumstances.

closer to their workplace). Likewise, governments can facilitate consumer choices by investing in public transit systems.

While most studies confirm that fossil fuel consumption responds to price changes and that demand is inelastic, the magnitude of the effect can vary substantially across countries and fuel types. For example, in the short run, a 10 percent rise in gasoline prices is estimated to reduce consumption by 2.1 percent in Türkiye, compared to 1.5 percent in Cameroon; but in the long-run, the reduction is only 4.8 percent in Türkiye, compared to a (more elastic) 14.3 percent in Cameroon (Erdogdu 2014; Sapnken et al. 2018). From these elasticity values, it is evident that the long-run response can be significantly larger than the short-run effect. Therefore, increasing fuel prices should have slow but lasting positive effects on air quality.

However, figure 1 suggests that energy consumption is on average *inelastic*; in other words, that consumption change in response to a price change is relatively small. An implication is that achieving meaningful reductions in fossil fuel consumption may require substantial increases in fuel prices, or complementary policy measures.

2.2. Case studies offer mixed evidence of the direct link between fuel prices and air pollution

To what extent do energy price changes affect air pollution outcomes? Perhaps surprisingly, the answer is not straightforward, as air pollution is driven by a range of factors, from affordability and availability of clean alternative technologies to fuel quality and regulatory requirements for public good technologies, such as air filters. This also means that, as well as targeting price levels, policy measures should improve the availability and affordability of clean alternatives, address information constraints and behavioral biases, and mandate the use of public good technologies.

In principle, higher fuel prices incentivize people to reduce travel, improve fuel efficiency, or find alternative means of transportation. Thus, by reducing the quantity of fuel used, price signals should lower air pollution levels. This channel between price and air quality—that changes in fuel prices affect consumption and hence air quality—has been studied in multiple urban settings, as far-ranging as the Islamic Republic of Iran, Australia, and China:

- A study on fuel prices and air quality in Teheran shows that a 10 percent increase in gasoline prices reduces carbon dioxide and particulate matter (PM10) concentrations, though only by 0.2 and 0.12 percent, respectively (Raeissi, Khalilabad and Hadian 2022). However, due to a substitution away from gasoline toward other fuels, the price rise also results in a 0.11 percent increase in nitrogen dioxide concentrations in the short-run, and a 0.2 percent increase in the long-run. Overall, the authors conclude that, while increasing fuel prices improves air quality, the effect is small and other measures—such as more rigorous regulation on vehicle pollution intensity—might prove more effective.

- Similar effects have been documented in Brisbane with respect to the impact of fuel price changes on air quality (Barnett and Knibbs 2014). Their findings indicate that, although higher fuel prices do not lead to a significant change in PM2.5 and PM10 concentrations, increasing diesel prices leads to substantial decreases in nitrogen oxide concentrations. They estimate that increasing the cost of diesel by AUS$0.15 per liter would have tangible health benefits, decreasing daily emergency hospital admissions by 2 percent or approximately 215 people per year.
- A study of 11 regions in China between 2006 and 2015 finds that vehicle volumes, energy consumption, and gross domestic product (GDP) per capita are all significantly correlated with increased PM2.5, PM10, and ozone concentrations (Xu et al. 2019), with increased vehicle volumes in particular consistently increasing pollution levels. However, another study of 21 cities in northern China shows that more than half of the major air pollutants (that is, PM2.5, PM10, and sulfur dioxide) originate from coal-fired heating in autumn and winter (Lin and Ling 2021). But changes in coal prices do not affect air pollution levels, as the government controls heating prices.

2.3. Entry points for mitigating air pollution

There are several reasons why the relationship between fuel prices and air pollution may not be as pronounced as that between prices and consumption. One explanation is the effect of available technology on the impact of price changes. For example, vehicle fleets with better fuel efficiency and exhaust filters would register a smaller change in PM2.5 concentration for the same reduction in distance traveled when compared to a "dirtier" fleet. Therefore, depending on fleet composition, PM2.5 concentration in some countries might respond more or less strongly to a price change. Additionally, as indicated by the higher-magnitude elasticities in the long run, responses to a price change might take time to manifest. For example, if switching from coal to liquefied petroleum gas (LPG) as a cooking fuel necessitates a new stove purchase, it might be difficult for households, and therefore take time. The price elasticity of gasoline demand also varies significantly between countries and cities. For example, it is easier for consumers to substitute away from driving in a city with a well-developed public transit system. Finally, fuels can have multiple uses, contributing to inelastic demand. For example, in countries where gasoline is a domestic power source as well as a transport fuel, demand is highly inelastic. Due to these factors, we expect there to be ample heterogeneity in the impact of prices on PM2.5 concentrations.

It is important to note that, while the results of this study provide some evidence on the efficacy of gasoline and diesel price changes, many other avenues for reducing air pollution are available. Non-price measures, such as technology mandates and catalyzer regulations, are underused and could improve air quality without diminishing consumption levels (UNEP 2021). And while 64 percent of countries have ambient air quality standards in legislative instruments, their distribution is lopsided toward developed countries. For example, while all EU countries have such regulation, only 40 percent of Commonwealth countries do. Therefore, encouraging the implementation of air quality legislation—such as mandatory filters and fuel mileage requirements for cars—could improve urban air quality. A single price adjustment alone will not curb air pollution; rather, a combination of measures need to work in tandem. This paper documents the role prices could play.

3. Data and methods

3.1. Data

To evaluate the relationship between fossil fuel prices and air pollution, we combine three datasets to construct a panel dataset with PM2.5 readings, GDP per capita, and fossil fuel prices and consumption for 133 countries.

First, we take surface PM2.5 concentrations in μg/m^3 from van Donkeelar et al. (2021), who estimate mean annual air pollution levels globally using satellite imagery from 1998 to 2019. PM2.5 measures anthropogenic fine particulate pollution, such as exhaust emissions from fuel combustion, and is adjusted to remove naturally occurring particles, such as desert dust and sea salt. As it is possible to choose among a host of locations within a country that could affect readings, we homogenize our data to the center of each country's capital city.

Second, we merge GDP per capita values, measured in 2017 international $ adjusted for purchasing power parity (PPP), from the World Bank's World Development Indicators database (World Bank 2021a).

Third, we use IMF fossil fuel price and consumption data for 220 countries from 1980 to 2021 for coal, LPG, diesel, petrol, natural gas, electricity, kerosene, biomass, and other oil products, all commonly used energy types (Parry et al 2021). This data is made available by the IMF, and combines source data from IMF and World Bank country desk datasets, as well as a range of secondary sources as detailed by Parry et al. (2021, Annex B). As not all countries have data for gasoline, diesel, and coal during the study period, we reduce the number of countries included to 133. Also drawing on Parry et al (2021), we use fuel consumption in tons of oil equivalent (toe) data from the International Energy Agency, adjusted to a per capita basis using population numbers from the World Bank database (World Bank

2021b). Consumption data is available for 148 countries from 2000 to 2019, which restricts the time dimension of the combined dataset for this study.

Overall, the unbalanced panel data we use contains 133 countries over a 20-year period (2000–2019), totaling 2,465 observations. Table 1 shows the summary statistics of the variables for 2017.

Table 1. Summary statistics for 2017 of the variables used in this study

	Mean	Standard deviation	Minimum	Maximum
PM2.5	16.84	15.54	1.27	90.45
Gasoline price	0.99	0.38	0.11	1.92
Diesel price	0.83	0.45	0.00001	2.32
Coal price	3.68	1.55	0.21	22.64
Gasoline consumption per capita	192.20	234.01	2.81	1,245.44
Diesel consumption per capita	344.19	478.16	2.37	4,619.94
Coal consumption per capita	256.20	448.54	-2.41	2,513.82
GDP per capita	22,099.75	22,366.75	773.57	126,183.70

3.2. Estimation methods

We model the relationship of PM2.5 concentrations, fuel prices, fuel consumption, and GDP per capita as follows:

$$PM2.5_{i,t} = \alpha_i + \beta_{1,i} p_{i,t} + \beta_{2,i} q_{i,t} + \beta_{3,i} GDP/cap_{i,t} + \theta_t + \epsilon_{i,t}$$

where PM2.5 is the annual average PM2.5 reading in the capital; α is the country-specific intercept; p is the fuel price in international $ (PPP); q is the quantity of fuel consumed per capita (in toe); GDP/cap is the GDP per capita in 2017 US$ (PPP); θ is the time trend; and ϵ is the error term for country i at time t. We use the CCE estimator to evaluate the model coefficients and outline our rationale for doing so in the remainder of the section.

Since time series econometrics offers a vast library of methods, we begin to narrow down potentially applicable estimators by first evaluating slope heterogeneity within the panel. Slope homogenous models, such as fixed effect models, assume that correlation coefficients in the model are similar between different panel members. In a setting with highly different units—as is the case with the country-level analysis conducted here—this assumption might not be appropriate. Using the adjusted delta test of Pesaran and Yamagata (2008) (table 2) to assess the heterogeneity among slope coefficients, we find that the p-value is 0.000 for all three fuels. This finding rejects the null hypothesis of slope homogeneity for the model, allowing us to exclude slope homogenous estimators and continue our search within estimators that account for slope heterogeneity.

Table 2. Results of the adjusted delta test

	Gasoline		Coal		Diesel	
	Delta	**p-value**	**Delta**	**p-value**	**Delta**	**p-value**
Unadjusted	14.099	0.000	13.676	0.000	14.933	0.000
Adjusted	17.145	0.000	16.431	0.000	18.174	0.000

Source: Based on the adjusted delta test of Pesaran and Yamagata 2008

Next, we proceed by determining the order of integration for each variable. Variables are said to be integrated of order *d* when they become covariance-stationary after taking *d* differences of former observations. In simple terms, *covariance stationarity* implies that the time series has finite moments over time; for example, the mean does not eventually diverge to infinity. Without this condition, it is likely that we need to account for regression coefficients becoming biased due to spurious correlation; for example, we may find a positive correlation due to two variables experiencing growth at the same time when there is no underlying relationship. Depending on the cross-sectional dependency (CD) structure within a panel data, we can use either first- or second-generation unit root tests for this. First-generation tests are appropriate under cross-sectional independence; otherwise, second-generation tests are appropriate. We determine which generation to use via Pesaran's (2004) CD test. As one might expect with macroeconomic variables, cross-sectional independence is rejected across the board for all variables, as is clear in table 3. So, we test the order of integration of the variables using the Cross-sectional Augmented Dickey Fuller (CADF) test developed in Pesaran (2003), and Newey and West's (1994) rule-of-thumb for the number of lags included (4(T/100)^(2/9)≈3). For the CADF test, the results reject the null hypothesis of stationarity for all variables with the smallest p-value being 0.473, associated with PM2.5 readings (table 4). Therefore, none of the variables can be made stationary using up to 3 lags of the variable, showing that the variables are nonstationary. Given the results of the preliminary tests, we decide to use Pesaran's (2006) CCE estimator, which is robust to CD and nonstationary data while allowing for slope heterogeneity, to estimate the model coefficients for all three fuels.

Table 3. CD test results

	p-value
PM2.5	0.000
Gasoline *p*	0.000
Gasoline *q*	0.000
Coal *p*	0.000
Coal *q*	0.000
Diesel *p*	0.000
Diesel *q*	0.000
GDP/cap	0.000

Source: Pesaran 2015

Table 4. CADF test results

	p-value
PM2.5	0.473
Gasoline *p*	0.631
Gasoline *q*	1.000
Coal *p*	1.000
Coal *q*	1.000
Diesel *p*	1.000
Diesel *q*	1.000
GDP/cap	1.000

Source: Pesaran 2003

Notes: p = fuel price (US$ PPP) ; *q* = quantity of fuel consumed per capita (toe) ; GDP/cap = GDP per capita (2017 US$ PPP).

4. Results

Overall, our analysis suggests the presence of a significant connection between gasoline and diesel prices and air quality, while the same does not hold for coal prices. Gasoline and diesel are extensively used in transport, which likely affects price responsiveness. So, when fuel prices are high, fuel consumers can opt to use alternatives, such as public transit, and freight transportation providers can reduce operations and invest in better fuel economy. In contrast, coal is frequently used in power generation, heavy industry, and residential heating, where reducing consumption has substantial competitiveness or well-being implications. Thus, we find evidence that the price-pollution channel is contingent on fuel application and therefore the price elasticity of consumption.

4.1. Diesel prices and PM2.5 air pollution

Estimates suggest that higher diesel prices reduce PM2.5 concentrations. The signs of the coefficients in table 5 are mostly in line with intuition—that is, negative for GDP per capita and positive for the time trend. Thus, it appears that capital cities in countries with higher incomes tend to have better air quality while global pollution levels increased from 2000 to 2019 when accounting for the other covariates. Contrary to intuition, diesel consumed per capita is positively correlated with better urban air quality. However, the results are not statistically significant for the time trend, diesel consumption per capita, and GDP per capita, indicating a substantial amount of heterogeneity across countries. Only the results for diesel prices are statistically significant at the 5 percent level, suggesting a 31.05 µg/m^3 decrease in annual PM2.5 readings in each country's capital city for each additional US$1 in average diesel price. Thus, our findings indicate that, on average, price hikes are correlated with a tangible decrease in PM2.5 concentrations. However, the low significance on the other covariates also highlights that there is substantial heterogeneity between countries, which could be due to differences in technology and/or price elasticities, as discussed in detail in section 2.

Table 5. CCE estimation results

	Coefficient	Standard error	P-value	Significance
$\boldsymbol{\theta}$	1.1949	6.3209	0.850	
$\boldsymbol{p}$	-31.0510	13.9865	0.026	**
$\boldsymbol{q}$	-0.2709	0.2531	0.284	
$\boldsymbol{GDP/cap}$	0.0098	0.0099	0.320	

Notes: θ = time trend; *p* = fuel price (intl $ PPP) ; *q* = quantity of fuel consumed per capita (toe) ; GDP/cap = GDP per capita (2017 US$ PPP); *** = significant at the 1% level, ** = significant at the 5% level, * = significant at the 10% level

4.2. Gasoline prices and PM2.5 air pollution

Similar to the results for diesel prices, the price of gasoline appears to be negatively correlated with air quality, as a US$1 increase in price per liter is tied to a 22.2 µg/m^3 decrease in PM2.5 concentrations, significant at the 10 percent level (table 6). Two of the three remaining coefficients are in line with expectation: the positively correlated time trend and the quantity of gasoline consumed. Contrary to earlier results for diesel, GDP per capita is negatively correlated with air quality. However, none of the three nonprice variables are statistically significant.

Table 6. CCE estimation results

	Coefficient	SE	P-value	Significance
θ	0.2825	4.0000	0.944	
p	-22.1996	12.7100	0.081	*
q	0.1532	0.2496	0.539	
GDP/cap	-0.0111	0.0075	0.138	

Notes: θ = time trend; p = fuel price (intl $ PPP) ; q = quantity of fuel consumed per capita (toe) ; GDP/cap = GDP per capita (2017 US$ PPP); *** = significant at the 1% level, ** = significant at the 5% level, * = significant at the 10% level

4.3. Coal prices and PM2.5 air pollution

In contrast to the other two fuels, results for coal are markedly different (table 7). Contrary to what one might expect, coal prices and GDP per capita are positively correlated with PM2.5 concentrations, whereas quantity of coal consumed is negatively correlated. The only semblance to the earlier results is the positive time trend. While this may reflect unexpected behavior, none of the results are statistically significant.

Table 7. CCE estimation results

	Coefficient	SE	P-value	Significance
θ	0.1018	0.9966	0.919	
p	0.7975	1.6634	0.632	
q	-0.3587	0.6144	0.559	
GDP/cap	0.0016	0.0027	0.542	

Notes: θ = time trend; p = fuel price (intl $ PPP) ; q = quantity of fuel consumed per capita (toe) ; GDP/cap = GDP per capita (2017 US$ PPP); *** = significant at the 1% level, ** = significant at the 5% level, * = significant at the 10% level

There are several possible explanations why national coal consumption may be highly inelastic to price variations. For example, coal-fired power generation serves baseload electricity and is not typically adjusted in response to short-term coal price variations. Instead, it is likely to operate continuously, with price variations absorbed by operators, which are frequently state-owned enterprises. A similar rationale may apply to industrial uses of coal—for instance, in steel production and manufacturing—where producing less in response to increased input prices may not be an option, and the additional cost is passed on to consumers instead. Moreover, this analysis focuses on PM2.5 particles, but coal combustion is associated with a range of other toxic pollutants, including sulfur dioxide and nitrogen oxides. Overall, our findings suggest that coal prices do not significantly and systematically alter urban PM2.5 concentrations in our sample of 133 countries. However, while this might hold globally, the relationship may be significant in different subsamples, such as regions or national income classifications.

5. Discussion

Exposure to air pollution is widely accepted as a leading health issue in many countries, regardless of income classification (WHO 2021). In urban environments, fossil fuel combustion is a significant contributor to airborne PM2.5, making fossil fuels an attractive target for regulation to improve health outcomes. While the relationship between fossil fuel prices and consumption has had ample attention in empirical economics, the cascading effect on air quality is less thoroughly studied. At a fundamental level, one would expect higher fuel prices to lead to lower consumption, which, in turn, would result in better air quality outcomes. Earlier works on the price-pollution channel have been at the city level and found mixed results regarding price impacts on air pollution; our contribution to the literature is in examining whether a relationship exists at the global level by using the CCE estimator with a novel panel dataset that covers 133 countries over 19 years.

Our results indicate a significant relationship between PM2.5 concentrations and the price of two transport fuels. For gasoline, a US$1 increase in prices yields 22.2 µg/m^3 reduction in PM2.5 concentrations; for diesel, the reduction is 31.05 µg/m^3. This trend seems to mirror findings in the literature, which has found that diesel prices in particular are effective in mitigating emissions. Both fuels are frequently used in public transit and freight transportation, and diesel is a major source of urban air pollution. Their consumption tends to be variable, as consumers can switch to alternatives, such as public transit, or invest in more fuel-efficient vehicles when prices are high. In contrast, we do not find a significant relationship between coal prices and PM2.5 concentrations. One possible explanation lies in the nature of coal use. Unlike gasoline and diesel, coal is often used in baseload power generation, heavy industry, and residential heating, where there is limited flexibility to react to price changes. Coal combustion is also associated with a range of other pollutants apart from PM2.5. Thus, we find that the pollution-price channel is heavily contingent on the nature of a fuel's application.

The analysis presented in this study is limited by the available data. Going forward, the analysis could be further improved by:

- Using a longer time-series with higher temporal frequency, to allow for more detailed analysis by including more variables and their lags.
- Assessing the role of technology on the price-pollution channel in more detail. For example, we could look at how the relationship differs in countries with easier access to exhaust filters versus others.
- Estimating the causal effect of price changes to pinpoint and isolate the role of price signals, for example, by using instrumental variables.

Our results on a negative relationship between prices and air pollution suggest that price-based instruments may be able to tackle urban pollution, but may not be able to solve PM2.5 pollution and its health impacts on their own. In many countries within our sample, a US$1 increase in fuel prices would constitute a substantial rise in price that would incur significant loss in consumer welfare and trigger political opposition. So, governments must use price measures in tandem with other policies—such as public transit investments and technology subsidies—to ameliorate urban air pollution.

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