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AIR POLLUTION AND INFANT MORTALITY: EVIDENCE FROM THE EXPANSION OF NATURAL GAS INFRASTRUCTURE

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Air Pollution and Infant Mortality: Evidence from the Expansion of Natural Gas Infrastructure
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ABSTRACT

Natural gas, as a relatively clean, abundant, and highly-efficient source of energy, has emerged as an increasingly attractive fuel in recent years. In this paper, we examine the impact of widespread adoption of natural gas as a source of fuel on infant mortality in Turkey, using variation across provinces and over time in the intensity of natural gas utilization. Our results indicate that the expansion of natural gas infrastructure has resulted in a significant decrease in the rate of infant mortality in Turkey. According to our point estimates, a one-percentage point increase in the rate of subscriptions to natural gas services would cause the infant mortality rate to decline by 4.1 percent, which would translate into in approximately 357 infant lives saved in 2011 alone. This finding is robust to a large number of specifications.

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I. Introduction

Concerns over the harmful effects of global climate change on people's health and communities around the world have raised widespread awareness for an urgent need to identify technologies and practices that would enable a carbon-free future. There is little dispute that burning of coal, which produces far more carbon than any other fuel, is a main contributor to global climate change and the worsening air quality in many parts of the world. Despite this consensus, consumption of coal continues to rise at a pace that now presents a formidable threat to some of the gains in health outcomes achieved by the developing world over the last several decades. Efforts to reduce carbon emissions through environmental regulations have produced little success because of resistance to strict legal obligations by emerging economies, which are facing mounting pressure to sustain their economic development.[1] Therefore, any viable solution to the problem of global climate change is likely to involve actions that are not only voluntary, but are also, and more importantly, in the economic interest of societies. One such action is the investments undertaken by countries, especially those of energy importing ones, in pursuit of diversifying their portfolio, so that their economies become less vulnerable to supply shortages or interruptions in any particular fuel. To the extent that the resulting portfolio is less carbon intensive, these actions may reduce air pollution levels and produce benefits for the environment and public health.

In this paper, we consider the health effects of one such action adopted by Turkey, which began investing heavily on building a natural gas infrastructure in 1980s by expanding a network of pipelines originating in its neighbors, including Russia and Iran.

[1] There are also challenges to effective enforcement of regulations due to weak governance and corruption, not to mention the costs induced by regulating emission levels (Jayachandran, 2009; Greenstone and Hanna, 2011).

This infrastructure, which has enabled 61 of the 81 Turkish provinces to gain access to natural gas to this date, has led to a widespread replacement of the consumption of dirty coal by natural gas for residential and commercial space heating and cooking purposes (Figure 1). Burning of natural gas emits virtually no sulfur oxide, which is a key component of acid rain. Furthermore, emissions of total particulate matter, carbon monoxide, and nitrogen oxide are also at much lower quantities from burning of natural gas compared to coal. Then an important question to consider is whether the expansion of the natural gas infrastructure has had any impact on infant health, such as mortality. To the best of our knowledge, the current study is the first attempt in the literature to examine the effects of a nationwide change in a fuel delivery system on infant health. The knowledge to be gained from this analysis has far-reaching implications as processes of similar investments have been taking place in other parts of the world, including Latin America, Europe, and Asia[2]. As the consumption of natural gas continues to rise, any effect may likely to be felt way beyond the borders of investing countries due to global circulation patterns of the air.

This investigation is particularly timely because of the recent spike in the supply of natural gas, made possible by an extraction technology called hydraulic fracturing or "fracking."[3] The impacts of fracking boom have been especially astounding in the United States, which has seen its natural gas production to rise by 25 percent since 2010 and recently outstripped Russia as the world's largest gas producer (Morse, 2014). The proponents argue that fracking is not only an economically sound practice, but also an

[2] Examples include the recently opened North Stream pipeline from Russia to Germany through the Baltic Sea, the ongoing South Stream pipeline project from Russia to Europe through the Black Sea, the Mazatlan pipeline project in Mexico, and Myanmar-China and Kazakhstan-China pipeline projects.

[3] Fracking involves the process of injecting sand, water, and certain chemicals into shale rocks to crack them open and release natural gas trapped inside.

environmentally friendly one as it replaces coal-fired power plants with those fired by natural gas. Accordingly, they argue that it could serve as a "bridge fuel" towards the eventual replacement of carbon-based fossil fuels by renewable energy sources (Podesta and Wirth, 2009; Paltsev et al., 2011). However, there is also deep skepticism among many experts and policymakers about the potential benefits of fracking for the environment and public health. They point to the potential damages that might be caused by gas extraction through fracking, including the release of methane, underground water contamination, discharge of toxic chemicals during the process, and physical impacts in the form of increased seismic activity, and argue that the net benefits may be negligible or even negative as a result (Finkel, 2011; Krupp, 2014; Caulton et al., 2014).[4]

This paper also extends the growing literature on air pollution and infant mortality in developing countries by using a novel source of variation from Turkey. Despite growing concerns about the harmful health effects of air pollution in developing countries, most of the available evidence on the subject comes from the United States and a few other developed countries (e.g., Chay and Greenstone, 2003a, b; Currie and Neidell, 2005; Currie, Neidell, and Schmieder, 2009; Currie and Walker, 2011; Currie, Greenstone, and Moretti, 2011; Knittel, Miller, and Sanders, 2011).[5] One explanation for the relative paucity of evidence from developing countries is the fact that policy changes and environmental regulations in the developing world are rare and weakly enforced,

[4] There is currently little evidence available on the health impacts of fracking (Mitka, 2012; Mash et al., 2014). However, this question is beyond the purpose of our paper.

[5] There are several explanations offered for the pathways through which prenatal exposure to air pollution can affect infant health. For example, it has been suggested that exposure to pollutants like carbon monoxide and particulate matter could lead to impaired fetal tissue growth through oxygen deprivation (Ha et al., 2001; Dejmek et al., 2000; Maisonet, Correa, and Jaakkola, 2004; Siddiqui et al. 2008; Li et al., 2003). The effects of air pollution can be damaging particularly for infants, whose lungs are not developed and immune systems are weak. It is also argued that air pollution can harm the infant through adversely affecting the health of the pregnant mother, for example, by weakening her immune system, which could then be detrimental for her fetus (Currie, Neidell, and Schmieder, 2009).

failing to generate enough variation in air pollution levels to detect statistically significant effects (Arceo-Gomez, Hanna, and Oliva, 2012; Tanaka, 2012). In the absence of exogenous sources of variation, the associations documented in much of the earlier research on air pollution and health may reflect the impact of omitted factors, such as socio-economic status, that are correlated with both pollution exposure and health outcomes. Only recently, researchers have responded to this challenge and turned their attention toward identifying exogenous sources of variation that could yield the causal impact of air pollution on health in developing country settings.[6]

In order to account for unobserved heterogeneity, we rely on the fact that natural gas was introduced to Turkish provinces at different times, i.e., a difference-in-differences type identification strategy, and the subsequent expansion has been gradual. In particular, we exploit both the variation in the timing of the introduction of natural gas across provinces over time and the rate of expansion of natural gas services, measured by the number of subscribers to natural gas services per 100 persons. As shown in Figures 1 and 2, the natural gas infrastructure and use have grown rapidly in Turkey between 2001 and 2011.

The results indicate that a one-percentage point increase in the rate of subscriptions to natural gas services would result in a 4.1 percent decline in infant mortality rate, which could translate into approximately 357 infant lives saved in 2011 alone. Our auxiliary analysis using supplemental data on total particulate matter

[6] For example, Jayachandran (2009) studies the impact of particulate matter on infant health using variation in pollutants caused by massive wildfires in Indonesia. Tanaka (2012) uses variation in the regulations on emissions from power plants to examine the impact of air pollution on infant mortality in China. Arceo-Gomes, Hanna, and Oliva (2012) exploit the number of thermal inversions as an instrument to investigate the impact of air pollution on infant mortality in Mexico City. Finally, Greenstone and Hanna (2011) examine the impact of air and water pollution regulations on infant mortality in India.

demonstrates that the reductions in infant mortality associated with the penetration of natural gas services are driven by the improvement in air quality.

II. Expansion of Natural Gas Infrastructure in Turkey

The Turkish economy has undergone a major transformation over the last two decades, which is marked by rapid growth and structural changes, such as privatization of state enterprises and integration into global economy.[7] During the same period, Turkey has also intensified its efforts to diversify its energy portfolio by investing in the construction of a network of natural gas pipelines. The country's close proximity to some of the world's largest natural gas producers such as Russia, Iran, and Azerbaijan, has especially played an important role in the country's decision to increase the share of natural gas in its energy mix.[8] These efforts have led to an expansion of natural gas networks across Turkish provinces, resulting in a gradual migration from coal to natural gas for space heating and cooking purposes by dwellings and businesses.[9] First introduced in Ankara in 1988 and followed by Istanbul and Bursa in 1992, the number of Turkish provinces with natural gas has grown rapidly over the period 2001-2011 (Figure 1). Naturally, the consumption of gas has risen. According to statistics from the International Energy Agency, the total consumption of coal and peat in Turkey increased

[7] Turkey's recognition as a candidate for European Union membership in December 1999 and the accession talks that started in 2005 have brought the country's environmental record under increased scrutiny. This has led to the Turkish government putting a number of legislations and regulations in place to improve energy efficiency and address environmental concerns, including flue gas desulfurization requirements on all newly commissioned coal-fired power plants, new by-laws on air pollution control from heating in 2005, 2007, and 2009, the ratification of the Kyoto protocol, and setting a unilateral target for carbon emissions introduced by the 2009 National Climate Change Strategy (International Energy Agency, 2009). Furthermore, the use of leaded gasoline was banned in 2004.

[8] Natural gas is imported from mainly Russia and a few other neighboring countries through pipelines that are operated by the state owned company, BOTAS, and is transmitted to individual provinces by private distribution companies. These companies are responsible for providing the public with clean burning natural gas by establishing and operating all infrastructural facilities for the utilization of natural gas.

[9] Number of provinces with natural gas infrastructure by year is as follows (2001 to 2004: 5 provinces; 2005: 13 provinces; 2006: 20 provinces; 2007: 31 provinces; 2008: 36 provinces; 2009: 54 provinces; 2010: 60 provinces; 2011: 61 provinces).

from 11 Million tons of oil equivalent (Mtoe) to 14 Mtoe between 2000 and 2010, while the total consumption of natural gas almost tripled from 4.9 Mtoe to 13.1 Mtoe during the same period (International Energy Agency, 2012). Similarly, the share of natural gas in electricity production increased from 37 percent in 2000 to about 46 percent in 2010. During the same time, the share of coal exhibited a small decline from 31 percent to 26 percent. In terms of residential use, the demand for natural gas exhibited an average increase of 28 percent between 1990 and 2009, while the demand for coal increased only by 3.6 percent (International Energy Agency, 2011). Similarly, the average annual increase in the industrial use of natural gas has been 10.6 percent compared to only 1.5 percent for coal during that period. The rise in natural gas consumption has resulted in a significant reduction in air pollution (Kaygusuz, 2007). More importantly, we show empirical evidence in Appendix that the increased natural gas utilization made possible by the expansion has resulted in a reduction in total particulate matter.

A number of factors are associated with the timing of the adoption and the rate of expansion of natural gas across provinces in Turkey. Our investigation suggests that these factors are primarily related to economic viability, and are unrelated to a particular plan designed to improve health outcomes. . This is comforting for our identification strategy, which we provide further empirical evidence about in Section IV. It is important to keep in mind that the investments in infrastructure required to expand natural gas grids to individual provinces are very costly and often take many years to recoup. Since the establishment and administration of infrastructure at the province level are controlled by privately owned firms, the factors associated with economic viability, such as the number of housing units (or the population size), the climate, the conditions of the geographic terrain, and the proximity to main natural gas ports administered by the government appear to play an important role regarding the timing of province level adoption (Aras and Aras, 2005). Therefore, it is not surprising that centrally located provinces with large populations and relatively cold and long winters, like Istanbul, Ankara, and Bursa, are among the early adopters. It is also not surprising that many of the remaining provinces without a natural gas infrastructure are located in the far eastern and southern regions of Turkey, areas that are both mountainous and distant from the main ports. Once a province gains access to natural gas, a household's decision to switch to natural gas for the purposes of heating and cooking can be voluntary, depending on the type of housing unit occupied by the household. For single household residential units, the decision is voluntary. For buildings with multiple housing, which constitute the vast majority of living arrangements in Turkey, a majority decision among the individual residents is required in order to change the system to either individual or central heating with natural gas.[10]

III. Data and Descriptive Statistics

Data on Natural Gas Intensity in Turkey

Data on natural gas variables come from the Dogal Gaz Dergisi (the Turkish Natural Gas Journal).[11] The number of provinces with natural gas infrastructure grew from 5 to 61 (out of 81) between 2001 and 2011 (Figure 1).[12] However, as shown in Figure 2, the rate of utilization has been gradual and is currently far from complete. Note

[10] Since our unit of analysis is at the province level, we are unable to distinguish the private and public health benefits associated with natural gas use. However, the analysis at the province level guards us against the potential endogeneity of a household's decision to switch to natural gas. Therefore, our estimates provide the combined effect of natural gas on those who benefit from cleaner air both privately and publicly.

[11] See http://www.dogalgaz.com.tr/

[12] Appendix Table 1 presents the list of provinces with natural gas infrastructure by 2011 along with the year of adoption and natural gas services subscription rates in 2011.

that there is considerable variation in the rate by which natural gas has expanded across provinces. To illustrate, we present the expansion of natural gas infrastructure for six select provinces, including Istanbul, Izmir, Bursa, Gaziantep, Kocaeli, and Erzurum in Figure 3. Note that the first four of these provinces are among the top ten in terms of population, while the last two are medium sized provinces. The figure shows that there is considerable variation across provinces both in terms of the year of adoption and the growth of the natural gas infrastructure.

Time-Variant Province Characteristics

We control for a vector of time-variant determinants of infant mortality in our empirical models. These variables are measured at the province-year level and include number of hospitals and hospital beds per 100,000 persons, percent with a high school degree, percent with a college degree, number of students per teacher in secondary schools, number of motor vehicles per 1,000 persons, unemployment rate, and number of physicians per 100,000 persons, an indicator variable for whether the province has a Family Physician Program, and an indicator variable for whether the party affiliation of the province's elected mayor is the same as the party governing Turkey.[13,14] We also control for income per capita, which is only available at the regional at the sub-regional level for our analysis period. [15] Data on province level populations are obtained from the

[13] In the period 2001-2011, Turkey had three general elections (2002, 2007, and 2011) and two local elections (2004, and 2009). The members of the Turkish Parliament are elected in general elections, and province and town mayors are elected in local elections. The Family Physician Program, aimed to improve and expand the provision of primary care services to the needy, started as a pilot program in the province of Duzce in 2005 and was later expanded to all of the 81 provinces by 2010.

[14] We create dummy variables that equal unity for observations with missing data on the explanatory variables.

[15] According the Turkish Statistical Institute, Turkey is classified into 12 regions, 26 sub-regions, and 81 provinces. These regions and sub-regions are based on clusters of adjacent provinces and are merely for geographic and statistical purposes. The Turkish Statistical Institute is the official governmental institute,

Turkish Statistical Institute (TurkStat) for years 2000 and 2007-2011 and from the Turkish Ministry of Health between 2001 and 2006.[16] Information on the Family Physician Program comes from the Ministry of Health. The remaining control variables are obtained from the TurkStat.

Table 1 shows the means and standard deviations for these characteristics for the full sample as well as various sub-samples. The provinces with and without access to natural gas differ from each other in a number of characteristics. For example, provinces with natural gas are more likely to have a mayor whose party affiliation is the same as the ruling party. This is not surprising in a country where the central government maintains major control over decisions on resource allocations and local investments. Provinces with access to natural gas also have higher number of motor vehicles, per capita income, hospital beds and physicians, individuals with college education, and a higher likelihood of having a family physician program initiated in the province by the government. Again these differences suggest that natural gas penetration is more likely in provinces that are wealthier, more urban, and with more educated populations. On the other hand, there is no difference in unemployment rate between the two types of provinces.

Infant Mortality Rate in Turkey

We obtained province-level infant mortality data from the TurkStat between years 2001 and 2008 and Turkish Census Bureau for the 2009 and 2011.[17] Our analysis sample

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which collects and processes data from a variety of different sources on numerous topics ranging from agriculture to health. See http://www.turkstat.gov.tr for more information.

[16] Since no Census was conducted between years 2001-2006, the province level population figures for the 2001-2006 are based on extrapolations implemented by the Ministry of Health. Alternatively, we imputed the population figures between 2001-2006 using province specific growth rates. Using these values produce results almost identical to those presented in this paper. These results are available from the authors upon request.

[17] The mortality records at the province level between 2009 and 2011 were not available from the TurkStat at the time this research was conducted. However, we were able to obtain data for these three years from

consists of 877 province-year observations between 2001 and 2011.[18] As shown in Table 1, the average infant mortality rate across all provinces and over the period of 2001 and 2011 is 9.27. However, the average infant mortality rate is higher among province-year observations with natural gas than those without natural gas. Similarly, there is a sharp difference in infant mortality rate between provinces which gained access to natural gas and those which never did during our analysis period.

Under-reporting in Infant Mortality Rate

It is widely recognized that official statistics on deaths, especially, among infants, are incomplete in most developing countries due to under-reporting (e.g., Greenstone and Hanna, 2011; Gruber et al., 2014; Victora and Barros, 2001; Anthopolos and Becker, 2010; Becker et al., 1998; Anderson and Silver, 1986).[19] Accordingly, there are usually vast differences in the infant mortality rates reported by the national statistical offices of individual countries and those released by international agencies such as the WHO and United Nations. The statistics compiled by these international agencies usually adjust for under-reporting by combining information from various demographic surveys, census data, the official vital statistics registries, and by using modeling assumptions in an attempt to reduce the impact of under-reporting (Gruber et al., 2014; Lopez et al., 2001).

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the Turkish Census Bureau. The data from the two sources are highly consistent. Moreover, year fixed effects would account for differences in the data collection procedures between the two agencies to the extent such differences exist.

[18] Fourteen observations with missing information on infant mortality are dropped from the analysis.

[19] For example, Gruber et al. (2014) study the effects of a healthcare reform implemented in Thailand on a health care utilization and infant mortality. The infant mortality rates that they obtained from the Thailand Ministry of Public Health exhibit large differences from those reported in the World Bank Development Indicator Database. As they report in Table C1, the vital statistics registry estimates are lower than those of the World Bank by a factor of about 2.5. In a recent paper examining the impact of environmental regulations on infant mortality in India, Greenstone and Hanna (2011) report that the city-level infant mortality data that they use are about a third of the rate measured from survey measures of infant mortality rates. In the absence of data on infant mortality from Indonesia, Jayachandran (2009) imputes deaths from "missing children" in the 2000 Census.

The underreporting in the official statistics is driven by a number of factors. For example, many deaths, especially those that occur outside of a hospital where risks are higher, go unrecorded (Gruber et al., 2014; Tangcharoensathien et al., 2006; Anthopolos and Becker, 2010). Underreporting is particularly common for home deliveries and when the newborn dies only a very short period after birth. In fact, it is not uncommon for midwives to announce deaths as stillbirth rather than a live birth followed shortly by death out of respect to a grieving family (Anthopolos and Becker, 2010). In countries like Turkey, the dead are usually buried shortly (typically before sundown or within hours) after death in accordance with the Islamic tradition, which may also exasperate the under-registering of infant deaths. Note that the under-reporting is mostly one-sided, i.e., there are far more unreported infant deaths than unreported live births that survive the first year in life (Anthopolos and Becker, 2010).

To illustrate the differences in data on infant mortality in Turkey from various sources, we present the average annual mortality rates from three different sources in Appendix Table 2. The first two columns report the average mortality rates based on estimates from the WHO and the United Nations. The third column shows the infant mortality rate obtained from the TurkStat. It is important to note that province level data on infant mortality do not exist from the WHO and the United Nations. The estimates from the WHO and United Nations rely on data from the TurkStat, summary birth histories conducted in the Turkish Censuses and data from various waves of the Turkish Demographic and Health Surveys (TDHS).[20] Therefore, any difference between these

[20] Among these Turkish data sources, the TurkStat vital statistics are the only source which provides annual infant mortality rate at the province level. The Turkish Demographic and Health Surveys are conducted once every 5 years by the Institute of Population Studies at Hacettepe University in collaboration with the Turkish Ministry of Health. These surveys are only representative at the national level, by urban and rural

three estimates arises from a combination of the way each organization incorporates information from these sources as well as their own adjustments for underreporting. While the national averages of infant mortality rate from the TurkStat are lower than those from the two other sources for every year, the trends in the TurkStat and the other two series are similar and the pairwise correlations are very high. In fact, the pairwise correlation is 0.97 for both the series between the TurkStat and the WHO series and the TurkStat and the United Nations series. Furthermore, the measurement error (or under-reporting) in the infant mortality rate data obtained from TurkStat is not a source of concern for our analysis as long as it is not correlated with the adoption and the rate of penetration of natural gas by Turkish provinces. Even under a scenario where such correlations are plausible, the province-specific linear and quadratic trends in addition to province fixed effects included in our models would likely capture those correlations. To illustrate this point more formally, suppose that the true infant mortality rate is $IMR_{pt}*$. Then the observed infant mortality rate can be expressed as

$$IMR_{pt}=IMR_{pt}*- k_{pt},$$

where $IMR_{pt}*=Actual\_Deaths_{pt}/Live\_births_{pt}$; $IMR_{pt}=Reported\_Deaths_{pt}/Live\_births_{pt}$; and $k_{pt}=Unreported\_Deaths_{pt}/Live\_births_{pt}$. As long as the measurement error (or under-reporting), k_{pt}, is uncorrelated with the natural gas intensity, the estimate of the impact of natural gas utilization on infant mortality would be unbiased. We cannot think of a plausible scenario to suggest that such a correlation could exist. One argument can be that there might be a positive correlation between the adoption of natural gas and overall

residence. Although the surveys allow analyses for some of the survey topics for the 12 geographical regions of Turkey, they are unavailable at the province level. Similarly, the Turkish Censuses are not available on an annual basis, and it is not possible to derive province level representative infant mortality rates from them either.

quality in the government services in health care. A failure to account for such heterogeneity would then cause the estimate of the impact of natural gas utilization on infant mortality to be biased upward. However, if the improved quality of care in hospitals results in an increased proportion of births delivered in hospitals rather than homes, then the extent of under-reporting in the infant mortality should go down. In essence, under-reporting should be near zero if all births are delivered at hospitals. In that case, our estimate would be biased downward. Note that, in all of our regressions, we control for the number of hospitals, hospital beds, and physicians per capita at the province level as well as an indicator for whether the province has adopted the Family Physician Program. Also the provinces that gain access to a natural gas infrastructure are typically more urban and higher average income than others. Then, it is plausible to assume that a smaller proportion of births are delivered at homes than hospitals in these provinces relative to low-income rural provinces. Furthermore, underreporting tends to be larger in poor and less urban provinces (Anthopolos and Becker, 2010), but these are also the provinces less likely to have access to a natural gas infrastructure.[21] It may also be argued that the improvement in the quality of health care services itself may account for some of the reduction in infant mortality rate. Note that we further guard against any bias from such omitted factors that may be correlated with both infant mortality and the adoption and expansion of natural gas services across provinces by controlling for province fixed effects and province specific linear and quadratic time trends in our models. In addition, we include region by year fixed effects in our most comprehensive

[21] In fact, the TurkStat vital statistics miss infant deaths from small villages and remote areas of each province due to reporting errors involved in death registries. The TurkStat birth statistics, however, cover the entire provinces including small village and remote area births. Hence, in comparison with other data sources, the TurkStat infant mortality rates could appear to be lower.

specification. Our estimate of the impact of natural gas services subscription rate on infant mortality rate remains remarkably robust to controlling for province specific trends and region-by-year fixed effects. Similarly, it may also be argued that natural gas penetration could lead to increased awareness among the public, pregnant women in particular, of the harmful effects of air pollution, inducing them to engage in avoidance behavior, which might then decrease their exposure to air pollution. Although any reduction in infant mortality can still be attributed to the treatment, the mechanisms would be different under this scenario. In any case, province specific linear and quadratic trends along with region-by-year fixed effects would control for these unobservables.

IV. Identification

As highlighted in the previous section, the algorithm to determine which province gets to access to a natural gas infrastructure is not random. To illustrate the differences between provinces with and without natural gas infrastructure further, we report results from several regressions in Tables 2A and 2B. Specifically, each cell in column (1) of Table 2A corresponds to an estimate from a separate regression of the binary indicator for whether a province has natural gas on each of the characteristics listed in Table 1 along with year fixed effects. Not surprisingly, the estimates in column (1) support the argument made above, i.e., those provinces with and without natural gas exhibit differences on a wide range of characteristics. However, accounting for permanent differences across provinces through province fixed effects in column (2) mitigates many of these differences both statistically and in magnitude. When we further add province-specific linear and quadratic trends and region by year fixed effects in the subsequent three columns, we observe that none of the characteristics considered in this analysis is associated with the indicator of natural gas. We obtain a very similar pattern when we repeat the same analyses using the natural gas subscription rate in Table 2B.

To gain further insights about the differences in observable characteristics between provinces with and without a natural gas infrastructure, we next run regressions of the binary indicator of natural gas infrastructure and the rate of natural gas subscribers on jointly specified time varying province characteristics. These results are shown in Tables 3A and 3B. Again, many of the control variables are significantly associated with the presence of a natural gas infrastructure or the natural gas service subscription rate in column (1), lending support to the notion that distribution of natural gas networks across provinces is non-random and thus could reflect some of the observed or unobserved factors that might also be correlated with infant mortality. However, all of these differences become statistically insignificant and much smaller in magnitude once we account for province fixed effects along with province specific linear and quadratic trends and region by year fixed effects through columns (2) and (5). This is also evidenced from the F-statistics and the corresponding p-values reported at the bottom of the table, which highlights the overall insignificance of all these characteristics once fixed effects and trends are accounted for. We interpret these findings as strong evidence to indicate that any remaining variation in the indicator for the presence of natural gas infrastructure or the rate of adoption of natural gas in column (5) is likely to be exogenous to infant mortality.

A natural question is whether other province level policy changes that are correlated with natural gas can threaten our identification strategy. It should be noted that central government has the ultimate authority for passing laws and implementing policies related to energy and health policy in Turkey. Consequently, policies are either implemented at the national level (e.g., health insurance expansion) or started as a pilot program and then expanded to all the provinces nationwide.[22] To account for the potential differential treatment effects by the central government at the provincial level, we control for whether the mayor of the province is affiliated with the governing party in addition to specifying for a full set of region-by-year fixed effects. As it is plausible that differential treatment by the central government would take place at the regional level rather than the provincial level, controlling for region specific time dummies should properly account for such differences.

Note that our identification strategy does not require the levels in infant mortality rates between provinces with and without natural gas to be equal prior to adoption of natural gas. Rather, it assumes that, in the absence of natural gas adoption, the rates of infant mortality could have trended similarly between the two types of provinces. Although we cannot test this assumption directly, we further assess the credibility of our research design by examining whether there are any systematic changes in infant mortality prior to provinces gaining access to natural gas. This can be done using an event study analysis, which would allow us to trace out the trend in the infant mortality rate year-by-year for the periods leading up to and following access to a natural gas infrastructure. In practice, we implement this by estimating a regression of the logarithm of infant

[22] It may also be argued natural gas adoption may influence migration decisions of households between provinces without natural gas and those with natural gas. The internal migration decisions are almost entirely determined by economic motives in Turkey and have largely resulted families moving from rural provinces to urban provinces over the last several decades. To the extent that families migrating into provinces with natural gas are from low socio-economic status, our estimates would be a lower bound. Data on the proportion of migrants by province are available from the TurkStat for the period 2008-2011. We estimated models of migration as a function of natural gas adoption and expansion along with other control variables. The estimates on the two natural gas variables were both small and imprecisely estimated, providing suggestive evidence that migration decisions are unrelated to natural gas. These results are available from the authors upon request.

mortality rate on a set of indicators for the years to and from the year of adoption natural gas up to five years, along with province and year fixed effects. The estimates from this analysis, which are presented visually in Figure 4A, indicate that there is no evidence of systematic changes in infant mortality in the years prior to gaining access to a natural gas infrastructure and that our results would not simply reflect continuation of long-run pre-existing trends. In Figure 4B, we display the measure of Natural Gas Intensity by year relative to the natural gas adoption date. When Figures 4A and 4B are considered together, the concurrence between the reduction in infant mortality and the diffusion of natural gas utilization becomes more apparent. Nevertheless, we also allow province specific unobservables to trend differently by including province specific linear and quadratic time trends in our specifications. Therefore, conditional on the time-variant characteristics, fixed effects, provincial time trends, we are assessing whether provinces with a more rapid penetration of natural gas also experienced a more rapid decrease in infant mortality than other provinces.

V. Empirical Framework

We begin our investigation of the effect of provincial natural gas adoption on infant mortality with the following empirical model:

$$IMR_{pt} = X_{pt}\,\beta_o + \beta_1 Any\_Natural\_Gas_{pt} + \varepsilon_{pt}, \quad (1)$$

where IMR_{pt} represents the natural logarithm of the infant mortality rate in province p and in year t.[23] X_{pt} is a set of exogenous determinants of infant mortality described above.

[23] It is common to use the log of infant mortality rate as opposed to the level in similar contexts (e.g., Murtin, in press; Ruhm, 2000; Tanaka, 2005; Farahani et al., 2009; Anand and Baernighausen, 2004; Flegg, 1982; Jamison et al., 2004). Those provinces in the treatment category that already have small levels of infant mortality rate may experience only small improvements in their infant mortality rate in response to the adoption of natural gas. This may be in contrast to provinces with high levels of infant mortality rate, which may experience large swings in infant mortality. However, we also estimate our models using the

The variable, $Any\_Natural\_Gas_{pt}$, is a binary indicator for whether the province p has natural gas in year t. Finally, the ε_{pt} is the unobserved determinants of infant mortality. Equation (1) estimates the effect of a binary treatment, which is also the most widely employed approach in the relevant literature. The coefficient, β_1, would measure any permanent shift in infant mortality rate associated with the adoption of natural gas, independent of the intensity of natural gas utilization in a province. However, it is important to note that once provinces gain access to a natural gas infrastructure, the penetration of natural gas within the province occurs gradually and at different rates across provinces. Since a binary treatment approach pools all treatment provinces together into one treatment group, the results cannot rule out the possibility that the effects are driven not by provinces that were most treated by natural gas adoption, but by ones that were less treated (Adorno et al., 2007; Chakrabarti, 2008). If this is indeed the case, then failing to recognize the continuous nature of the treatment may lead to misleading conclusions. This issue may be particularly important in our case, where the intensity of treatment exposure changes considerably across provinces and over time. Therefore, the model specified in equation (1) is unlikely to fully capture the true impact on infant mortality rate associated with the adoption of natural gas.[24] Furthermore, policymakers may be interested in the effects of different levels of natural gas intensity, which one cannot discover by using a binary treatment model. To address these issues, we extend the model in equation (1) by including a variable that represents the rate of

level of infant mortality rate as the outcome and the results from these models are very similar to those presented here and are available from the authors upon request.

[24] As an example, consider the extreme case where every province has a natural gas infrastructure in place, but nobody utilizes it as a fuel source. Since our treatment indicator is defined at the province level, a binary treatment model may fail to reveal the effect of actual utilization in this case, which should be zero.

intensity of natural gas utilization at the province level. The new specification takes the form:

$$IMR_{pt} = X_{pt}\,\beta_o + \beta_1 Any\_Natural\_Gas_{pt} + \beta_2 Natural\_Gas\_Intensity_{pt} + \varepsilon_{pt}, \quad (2)$$

where $Natural\_Gas\_Intensity_{pt}$ represents the measure of natural gas intensity defined as the number of natural gas service subscribers per 100 persons in province p and in year t. The number of subscribers is the total number of household and business units with access to natural gas. The coefficient of interest in equation (2) is β_2, the impact of the rate of natural gas intensity on infant mortality rate. However, the causal interpretation of the coefficient β2 is complicated due to omitted variables that are likely to be correlated with both the availability of natural gas infrastructure and infant mortality. For example, as shown in Table 1, provinces with natural gas infrastructure are more likely to be urban, industrial, and with more motor vehicles per capita. Therefore, these provinces may also have higher levels of infant mortality despite gaining access to a natural gas infrastructure. In order to control for the effect of these factors, we rely on the longitudinal nature of our data and incorporate a series of fixed effects into equation (2):

$$IMR_{pt} = X_{pt}\,\beta_0 + \beta_1 Any\_Natural\_Gas_{pt} + \beta_2\, Natural\_Gas\_Intensity_{pt} + \omega_p + \lambda_t + \tau_{pt} + \tau^2_{pt} + \varepsilon_{pt}, \quad (3)$$

where ω_p is a set of province fixed effects that would capture any permanent differences across provinces and λ_t is set of year fixed effects that would account for any unobserved factors common to all provinces. It may be important to consider that some of the unobserved differences between provinces with and without natural gas may be time-variant. For example, some provinces that gain access to a natural gas infrastructure might have been experiencing a worsening (or a slower decrease in) infant mortality rate compared to other provinces. Although we find no such evidence in the event study analysis, we still guard against such possibility by controlling for province-specific linear and quadratic time trends as denoted by τ_{pt} and τ^2_{pt} in equation (3). Therefore, equation (3) accounts for differences across provinces in both levels and trends in the rate of infant mortality, and identifies the effect of natural gas as deviations from those trends. This is a stringent approach as it examines whether the expansion of natural gas consumption has an impact on infant mortality that can be distinguished from linear and quadratic trends. Finally, we further enrich the specification in equation (3) by controlling for region by year fixed effects that would account for any spillovers to neighboring provinces as well as any time-variant differences in unobserved heterogeneity that are common to provinces within a region.[25] As mentioned previously, the capital outlays for natural gas network expansions are provided by the central government. Due to economies of scale, provinces within a particular region may gain access to a natural gas infrastructure as a cluster, although we see little evidence of that in Appendix Table 1. It is also possible that households in regions experiencing rapid economic growth may collectively advocate for increased natural gas availability in their regions. Therefore, in addition to accounting for regional level income shocks, controlling for region specific time dummies would also account for factors such as the availability and expansions of natural gas networks at the regional level.

VI. Results

[25] The busier economic activity in certain regions like Marmara, which includes major urban and industrial hubs like Istanbul, Bursa, and Kocaeli, may have effects on all the provinces within that region. For example, Bursa and Istanbul are connected to each other through highly congested routes that have to pass through Yalova, a smaller and less urban province within the same region. Therefore, any air pollution, for example caused by the traffic congestion between Bursa and Istanbul, may also contaminate the air in Yalova. Controlling for region by year fixed effects would mitigate concerns about the aggregate effects of these factors.

We begin by presenting the estimates of the impact of *Any Natural Gas* on logarithm of infant mortality rate in Table 4A. Column (1) presents the estimate for the binary indicator of any natural gas adoption on infant mortality without any control variables. Column (2) adds year fixed effects and column (3) incorporates both year and province fixed effects that control for permanent differences across provinces. In columns (4) and (5), we add province-specific linear and quadratic time trends, and in column (6) we control for time varying province characteristics. Finally, in column (7) we show estimates from a specification that also accounts for region-by-year fixed effects. Standard errors are robust to any form of heteroscedasticity and clustered at the province level to allow for correlation at a given time and across time within provinces (Bertrand et al., 2004).

The estimates in the first two columns of Table 4A are positive, large in magnitude and statistically significant, suggesting that natural gas infrastructure is positively correlated with infant mortality. This is consistent with the earlier evidence that we presented, and suggests that provinces with and without natural gas infrastructure differ in ways that are correlated with infant mortality. For example, provinces with natural gas are more likely to be urban and industrial than others. Since urbanization and industrialization are likely to be positively correlated with infant mortality, failing to control for these differences would cause the estimate on any natural gas indicator to be biased downward, and like in our case, to possibly to switch sign. As expected, accounting for permanent province characteristics in column (3) makes a dramatic impact on the estimate of the effect of any natural gas and causes its sign to switch to negative. Specifically, once we control for province fixed effects, having access to a natural gas infrastructure is associated with a 27.1 percent decrease in infant mortality rate. However, as we explained in the previous section, it is not clear whether this estimate provides an accurate picture of a treatment that takes effect gradually. In fact, the estimate becomes small in size and statistically insignificant when we add province-specific linear and quadratic time trends in columns (4) and (5). This is not surprising given that a binary treatment model imposes a homogenous treatment effect, including for provinces with rapidly expanding natural gas infrastructure and those with near zero natural gas intensity levels for a long period of time. Adding time varying province characteristics in column (6) matters little. Finally, the estimate on any natural gas increases somewhat, but remains statistically insignificant when we estimate our richest specification with region-by-year fixed effects in column (7). In succeeding discussion, we focus our attention to the intensity of the natural gas utilization measure. But it is worth noting that estimating these models without controlling for the any natural gas indicator does not change the estimate on the natural gas intensity variable.

Next, we turn our attention to our main models specified in equations (2) and (3), which employ our intensity of natural gas measure. The results from these models are shown in Table 4B.[26] The estimates on the natural gas intensity variable and any natural gas indicator are still positive and significant in columns (1) and (2), a finding, which is again expected since these specifications do not account for differences across provinces. Once province fixed effects are controlled for in column (3), both estimates switch signs and become negative in line with our predictions. According to the point estimates, a one-percentage point increase in the natural gas intensity lowers the infant mortality rate by

[26] We also estimated weighted regressions using the mean population density and birth density as a weights. These estimations, shown in Appendix Table 3, did not cause any appreciable changes to the results presented here.

4.3 percent and the estimate is statistically significant at the one percent level. The estimate on the any natural gas indicator is also negative pointing to a 21.6 percent decrease in infant mortality associated with the presence of a natural gas infrastructure in a province. In the following two columns, we present estimates from specifications, which successively add province-specific linear and quadratic trends. Allowing for differential trends in the infant mortality rate across provinces does not cause any appreciable change to the estimate on the impact of natural gas services subscription rate. Furthermore, the estimate on the natural gas adoption year decreases in magnitude substantially and is no longer statistically significant.

If our identification strategy is credible, then the province fixed effects and trends should capture all of the time-variant and -invariant confounding factors correlated with both natural gas adoption and infant mortality. Therefore, as indicated by Tables 2A through 3B, adding time-variant characteristics of provinces should not cause any appreciable changes to our estimates. As shown in column (6), this is indeed the case in our analysis. In particular, controlling for a comprehensive set of time varying differences across provinces does not change the estimate on the effect of natural gas services subscription rate on infant mortality. In essence, once permanent differences across provinces are accounted for, the natural gas adoption can be considered as a natural experiment. Finally, in column (7) we present the results from a specification that also controls for region by year fixed effects along with all the other variables included in the previous columns. Controlling for region by year fixed effects is likely to help mitigate the impact of positive spillovers on air quality enjoyed by provinces without natural gas that are bordered to provinces in the treatment group. If the rate of infant mortality is reduced in control provinces because of the cleaner air in adjacent provinces that are in the treatment group, this may cause our estimate to be a lower bound. This specification could also account for any differences in region level government policies, such as healthcare interventions and university hospitals that typically serve entire regions. As it turns out, controlling for region by year fixed effects leaves the estimated coefficient on natural gas services subscription rate unaffected. In particular, the coefficient estimate presented in column (7) indicates that the effect of natural gas penetration rate on infant mortality rate is 4.1 percent.

To put these estimates into context, we next present some simulation results. For instance, as shown in Table 1, the average natural gas services subscription rate is 7.9 per 100 persons in province-year observations with natural gas infrastructure. In 2011, there were 8,714 infant deaths for 1,087,933 births in the provinces with a natural gas infrastructure, yielding an infant mortality rate of about 8 per 1,000 births. Holding the number of births constant, this would suggest that there could be approximately 357 fewer infant deaths in these provinces in 2011 in response to a one-percentage point increase in the natural gas services subscription rate.

Robustness and Sensitivity Analyses

The results presented above could be driven by either a decrease in the numerator (number of children who die in their first year) or an increase in the denominator (the number of live births). For example, the results could be driven by an increase in the denominator if the natural gas adoption is associated with an increase in the overall quality of health care services. As explained previously, this is unlikely since we control for the number of hospitals and hospital beds per capita along with the number of physicians per capita and an indicator for whether the province implements a family physician program. Furthermore, province level linear and quadratic trends should also help gauge these effects. Another possibility is that the improvements in air quality may lead to a reduction in the number of stillbirths and miscarriages, which would result in an increase in the number of live births. We test this by estimating our models with the logarithm of infant deaths as the dependent variable and the logarithm of births as an additional control variable (Arceo-Gomez, Hanna, and Oliva, 2012). As presented in Panel A of Table 5, performing this test yields estimates that are very similar to those in Table 4B when province fixed effects, province specific linear and quadratic time trends and region-by-year fixed-effects are specified. Therefore, it is unlikely that our results are driven by an increase in births. Next, we estimate models using logarithm of births as an outcome. As shown in Panel B of Table 5, the estimates in specifications from columns (3) to (7) are all zero, suggesting that natural gas adoption does not have an effect on the number of babies born.

Note that we use data from all 81 Turkish provinces in our analysis. Among these provinces, 20 of them have never accessed to a natural gas infrastructure during our analysis period. To test for the possibility that there is something fundamentally different about these provinces that may be affecting our results, we estimate our models excluding these provinces from the analysis. Results from the estimation of these models are presented in Panel A of Table 6. The pattern obtained here is indistinguishable from the one in Table 4B. Specifically, the estimate in our richest specification shown in column (7) is -0.041, which is identical to the one in Table 4B.

Next we assess whether our results are driven by provinces that always had natural gas during our analysis period. We start with re-estimating our models by excluding Istanbul, which, with its 13.5 million citizens, accounts for over 18 percent of Turkey's total population.[27] As shown in Panel B of Table 6, the results again remain almost identical to those in Table 4B when we perform this exercise. In Panel C, we repeated the same exercise by excluding, Ankara, Bursa, Eskisehir, Istanbul and Kocaeli, which are the provinces that always have had access to natural gas during our analysis period. Again, excluding these provinces does not have any bearings to our results. Taken together, results presented in Table 6 suggest that the main finding shown in Table 4B is not driven by systematic differences between provinces with and without natural gas.

The specifications we estimated assume that the natural gas intensity is linearly related to the infant mortality rate. However, this does not have to be the case if, for example, reductions in air pollution are more beneficial at higher levels of air pollution than lower levels of pollution. Then any gains in infant mortality associated with the intensity natural gas use may be higher at the early stages of adoption to natural gas than later stages. To assess the possibility of a non-linear relationship between natural gas intensity and infant mortality rate, we estimate our main specification with both linear and quadratic natural gas intensity measures. This exercise did not change any of the implications of the previously discussed results. Specifically, the estimates on the linear

[27] Istanbul is also one of the largest urban and busiest agglomerations in the world and responsible for over a quarter of Turkey's GDP. Concurrent with the expansion of natural gas infrastructure, Istanbul has experienced a rapid transformation in a multitude of dimensions during the period of our analysis. For example, it saw a surge in the number of private hospitals, which doubled in numbers between 2000 and 2005. Although we control for a number of variables related to the capacity and quality of health delivery services in our models, it may be argued that there remain other related factors that might have coincided with the expansion of natural gas services. One particular candidate is the mass-transit underground railway network, which entered service in 2000 and has caused a major relief in traffic congestion. Then the question is whether and to what extent the control variables and various fixed effects in our models account for these developments in a potential outlier like Istanbul.

and quadratic terms for natural gas intensity in the most comprehensive specification (column 7) are -0.061 and 0.001, respectively, where only the former is statistically significant at the 10 percent level. Given that the quadratic term is zero in both economical and statistical terms, the causal relationship between natural gas intensity and infant mortality rate is likely to be a linear one.

Note that our intensity of natural gas variable is defined as the number of subscribers to natural gas services per 100 persons. It may be argued that it would be more informative to produce estimates based on a measure of natural gas intensity per household numbers. Unfortunately, the TurkStat sources provide information on the province level household figures only for 2000 and 2011. Nevertheless, we generated proxy figures for the province level household numbers for each of the 81 province for all other years assuming that the growth rate for household figures is linear over time. Using these proxy figures, we then constructed a measure of subscription rate per 100 households and estimated our main specification with the new measure. Results from this exercise did not change any of the implications presented above. More specifically, the estimate on the proxy measure of subscribers per 100 households is -0.011 (p=0.05), suggesting that a one-percent increase in the subscription rate per 100 households would lead to a 1.1 percent decrease in infant mortality rate. If there are roughly 3 to 4 persons per household, then the effect size of 1.1, which is roughly a quarter of our main estimate is sensible.

A closer look over Figures 1 and 2 reveals that province level natural gas subscriptions rate exhibited a tenfold increase among the provinces with natural gas between 2001 and 2011, and these increases mainly took place after 2005. Accordingly, we would expect that, if we take 2001 as the reference year, the effect of natural gas use on the rate of infant mortality should be relatively greater towards the end of the analysis period, i.e., 2011, in comparison to when provinces started to adopt natural gas (i.e., 2005). To explore whether this is the case, we re-estimate our models by using two data points, initial and end dates, for each province for the periods 2001-05, 2001-07, 2001-09, and 2001-11, respectively. This implementation is similar to the long-difference estimation used in several other studies (e.g., Acemoglu and Johnson, 2007). This estimation methodology would also allow us to test whether our results are driven by the systematic differences between provinces with and without natural gas. Specifically, if the long-difference estimates between 2001 and the middle of the analysis period (i.e., 2005 or 2007) are similar to the long-different estimates between 2001 and the end of the analysis period (i.e., 2009 or 2011), then it is possible that our results reflect one or a combination of factors that make the two types of provinces different from each other in ways correlated with infant mortality. Long-difference estimates for *Natural Gas Intensity* and *Any Natural Gas* are shown in Panels A and B of Table 7. In line with our initial hypothesis, by the middle of the analysis period (i.e., 2005 and 2007), neither of the natural gas use indicators are meaningfully associated with infant mortality. However, both natural gas measures become statistically significantly associated with infant mortality towards the end of the analysis period. Therefore, the results, shown in Table 7, further strengthen our argument that our main findings are unlikely to be driven by systematic differences between province groups with and without natural gas infrastructure.

VII. Conclusions

Industrialization and economic development have brought with it dramatic improvements in living conditions of vast populations in developing countries through higher incomes and better health care. However, these benefits have come at the substantial cost of deterioration in environmental conditions and air quality, which threatens some of these gains achieved by these countries. Furthermore, there are very few viable policy options or enforcement mechanisms available to developed countries or international environmental organizations that could induce developing countries to take meaningful steps toward addressing environmental problems. One policy instrument commonly used to control air pollution is regulations. However, there are serious challenges to implementing regulations successfully, especially in developing countries, due to weak governance and corruption problems. Furthermore, concerns over global climate change are often sidelined in these countries due to a strong desire to maintain robust economic growth. Under these circumstances, natural gas has become a popular source of fuel and one that could help efforts to limit carbon emissions globally without causing interruptions in the mounting energy needs of these countries in the short run.

In this paper, we consider the impact of widespread expansion of natural gas services for residential and commercial use on the rate of infant mortality in Turkey. To identify this impact, we utilize the variation in the timing of deployment and intensity of expansion of natural gas infrastructures across Turkish provinces between 2001 and 2011. Our results indicate that the expansion of natural gas services leads to a significant reduction in the rate of infant mortality. The estimate from our most comprehensive model suggests that a one-percentage point increase in the rate of subscriptions to gas services would cause the infant mortality rate to decrease by 4.1 percent.

Our finding is especially useful in light of the ongoing public and political debate about the future of fracking revolution that has recently started in the United States and is now spreading elsewhere. Extraction of natural gas through fracking has become a wildly popular practice in the United States. Advocates argue that there are real environmental benefits to fracking because natural gas replaces dirty coal. As suggested by our findings, there are indeed sizeable health benefits to a widespread replacement of coal by natural gas. However, fracking has also its sharp critiques, who raise concerns over this practice in relation to underground water contamination, the physical impacts in the form of seismic activity, and the discharge of toxic chemicals to the surface during the process. If these concerns can be addressed, then there may indeed be real and widespread health benefits associated with fracking. But until the environmental impact of fracking is fully assessed, the net effect of this practice on health will remain ambiguous.

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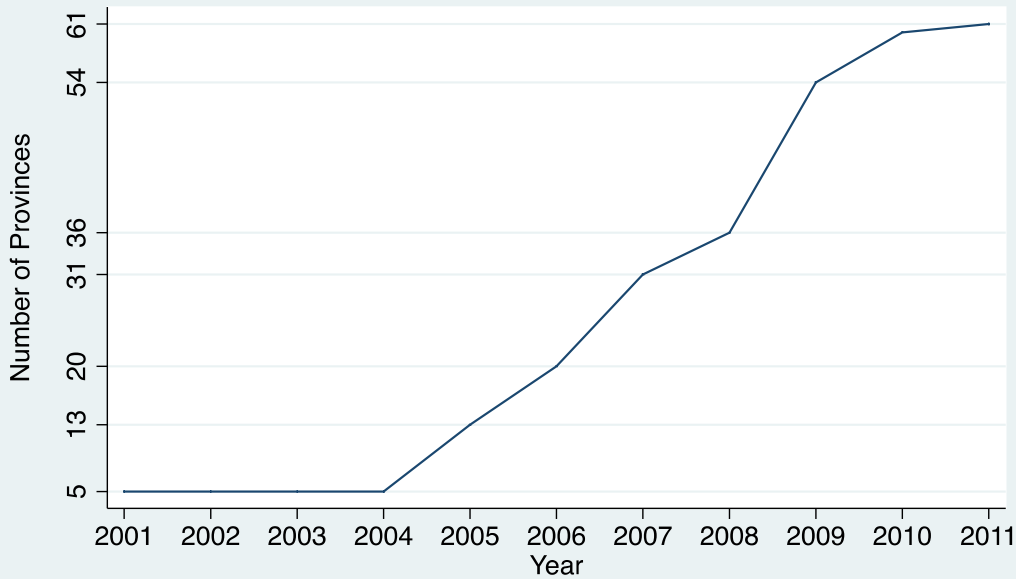
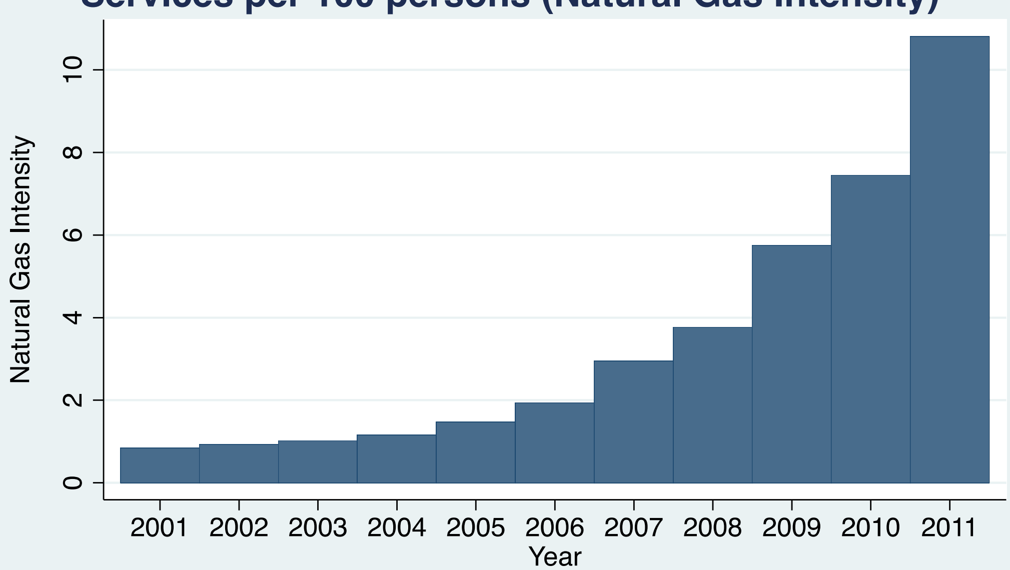
Figure 1: Number of Provinces with Natural Gas Infrastructure



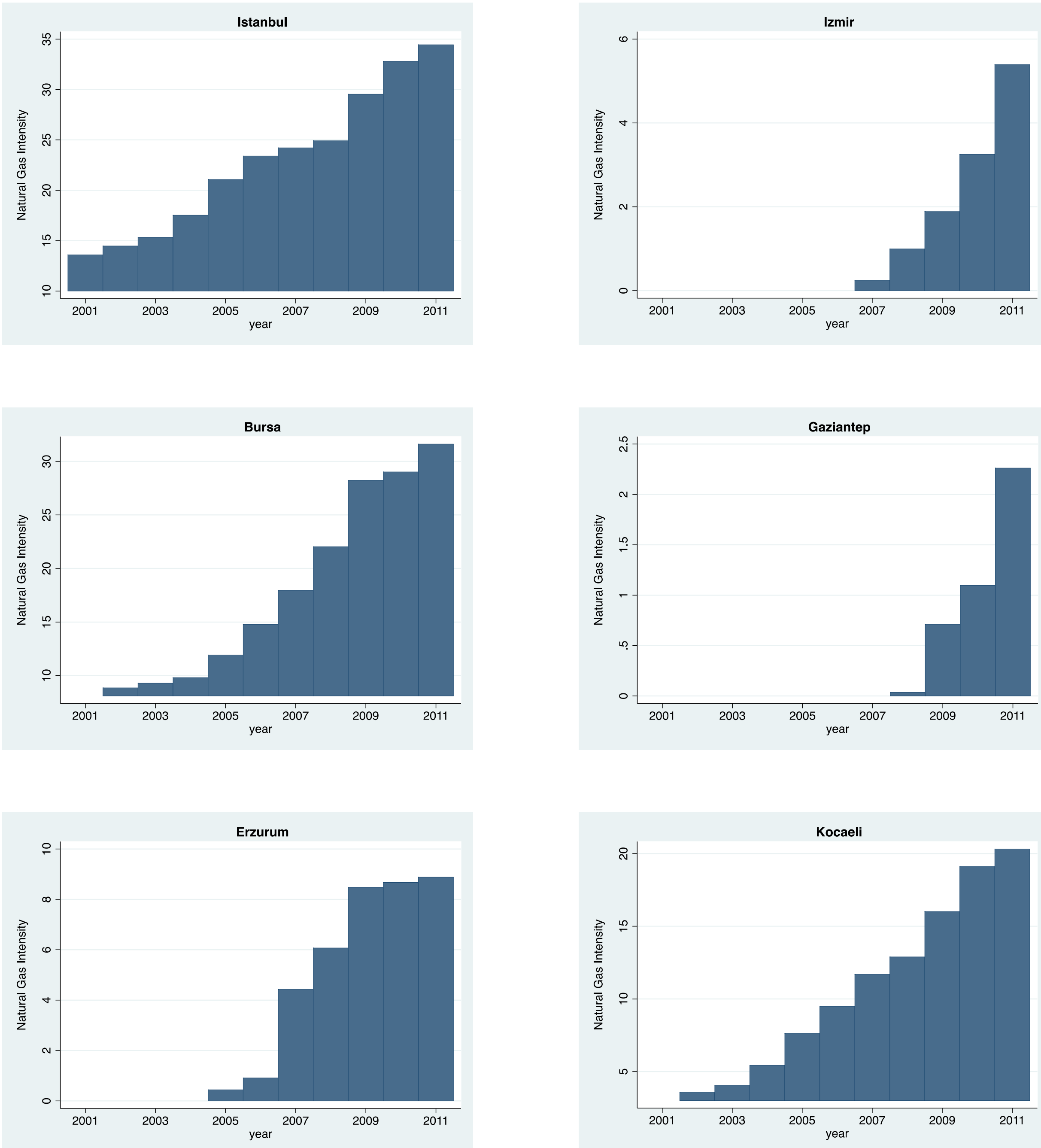
Note: There are 81 provinces in Turkey.
Source: Natural Gas Journal.

Figure 2: The Number of Subscriptions to Natural Gas Services per 100 persons (Natural Gas Intensity)



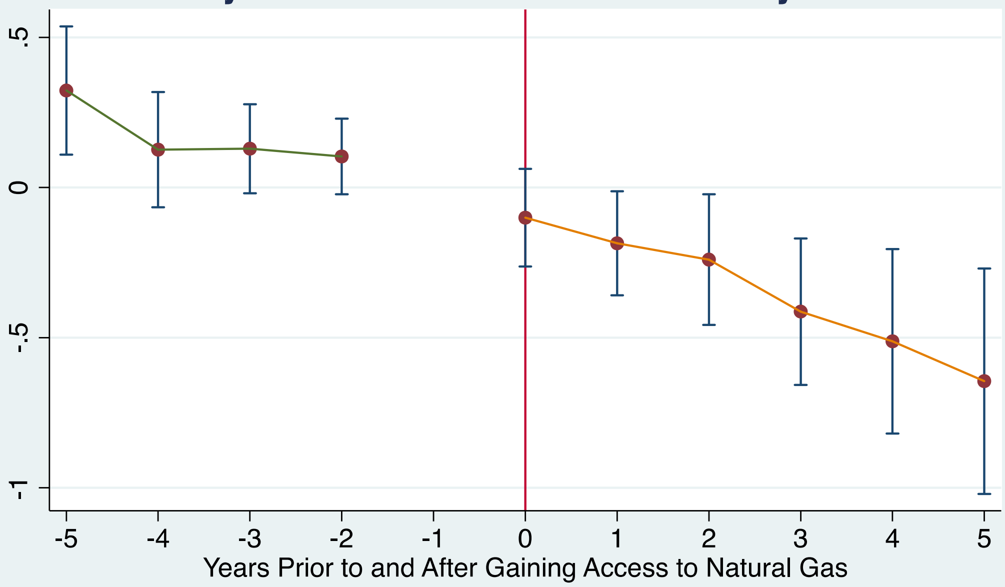
Note: The sample only consists of provinces with access to natural gas services at least one year during the period of 2001-2011.
Source: Natural Gas Journal.

Figure 3: Natural Gas Intensity in Select Provinces



Source: Natural Gas Journal.

Figure 4A: Event Study Estimates of the Effect of Any Natural Gas on Infant Mortality Rate



Notes: The figure displays coefficients and 90% confidence intervals. The reference category is one year prior to gaining access to natural gas.

Figure 4B: Natural Gas Intensity Rates After Gaining Access to Natural Gas

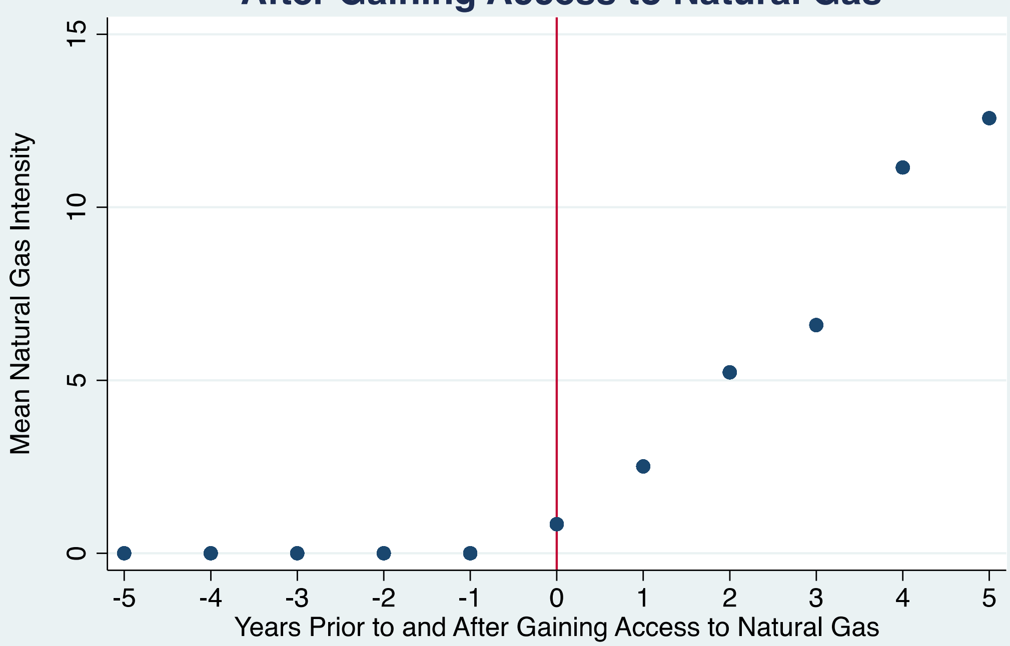


Table 1: Descriptive Statistics

Variable	(1) ALL	(2) Any Natural Gas = 0	(3) Any Natural Gas = 1	(4) Ever Had Natural Gas = 0	(5) Ever Had Natural Gas = 1
Infant Mortality per Thousand Births	9.148	8.003	8.881***	3.138	10.017 ***
	(1.171)	(1.114)	(1.069)	(1.685)	(1.560)
Any Natural Gas*	0.336	---	---	---	0.442
	(0.473)				(0.497)
Natural Gas Intensity**	2.648	---	7.871	---	3.476
	(6.142)		(8.435)		(6.831)
Ever Had Natural Gas	0.762	0.641	---	---	---
	(0.426)	(0.480)			
Average Particulate Matter (μg/m^3)	66.194	62.712	70.611***	78.941	63.519***
	(30.611)	(34.188)	(24.739)	(37.151)	(28.388)
Hospitals Per-100 K Population	2.063	2.052	2.089	2.185	2.025***
	(0.924)	(0.982)	(0.767)	(1.158)	(0.835)
Hospital Beds Per-100 K Population	214.041	196.613	255.971***	159.178	231.214***
	(90.357)	(88.541)	(80.520)	(76.415)	(87.544)
Physicians Per-100 K Population	125.472	107.555	143.210***	94.378	135.426***
	(51.076)	(39.063)	(55.300)	(23.170)	(53.535)
Per-capita Regional GDP	7.770	6.768	10.539***	5.509	8.467***
	(3.458)	(2.835)	(3.524)	(2.399)	(3.439)
Percent High School	16.163	15.489	17.019***	14.296	16.744***
	(3.284)	(3.274)	(3.096)	(3.094)	(3.123)
Percent College	6.676	5.654	7.975***	5.194	7.137***
	(2.570)	(1.987)	(2.643)	(2.121)	(2.525)
Students Per-Teacher	16.913	17.485	15.914***	19.732	16.031***
	(4.379)	(4.929)	(2.949)	(6.099)	(3.212)
Unemployment Rate	10.263	10.315	10.196	10.540	10.177
	(3.762)	(4.232)	(3.067)	(4.383)	(3.547)
Province Has Family Physician Program	0.281	0.134	0.570***	0.234	0.295*
	(0.450)	(0.341)	(0.496)	(0.425)	(0.456)
Motor Vehicles Per capita	161.443	134.716	195.424***	104.133	179.285***
	(78.350)	(79.156)	(62.680)	(87.458)	(65.876)
Governing Party	0.609	0.538	0.749***	0.455	0.657***
	(0.488)	(0.499)	(0.434)	(0.499)	(0.475)
Population	884.199	609.654	1425.845***	366.738	1046.100***
	(1460.947)	(540.491)	(2310.550)	(237.456)	(1635.670)
Observations	877	582	295	209	668

Notes: Standard Deviations are in parentheses. *, **, and *** indicate that mean is statistically different between the sample in columns (2) and (3) or columns (4) the 10%, 5%, and 1% levels, respectively.

*Any Natural Gas is set equal to 1 if the province has > 0 natural gas subscriptions.

**Natural Gas Intensity is defined as the number of natural gas subscriptions per 100 individuals.

Table 2A: Estimates of Any Natural Gas on Time Varying Observable Province Characteristics

Variable	(1)	(2)	(3)	(4)	(5)
Hospitals Per 100K	-0.049**	-0.014	-0.022	-0.067	-0.059
	(0.024)	(0.036)	(0.026)	(0.045)	(0.046)
Hospitals Beds Per 100K	0.001**	0.000	0.000	-0.001	0.000
	0.000	(0.001)	(0.001)	(0.001)	(0.001)
Physicians Per 100K	0.003***	0.003*	-0.002	-0.001	-0.002
	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)
Percent High School	0.041***	0.034**	0.023	0.005	0.003
	(0.009)	(0.014)	(0.015)	(0.016)	(0.024)
Percent College	0.060***	0.026	0.019	0.007	0.009
	(0.011)	(0.020)	(0.018)	(0.019)	(0.026)
Students Per Teacher	-0.017***	0.01	0.005	-0.004	0.002
	(0.005)	(0.006)	(0.004)	(0.008)	(0.007)
Unemployment Rate	-0.011	-0.015*	-0.002	-0.004	0.016
	(0.008)	(0.008)	(0.007)	(0.008)	(0.014)
Family Physician Program	0.052	0.021	-0.045	-0.018	-0.021
	(0.092)	(0.062)	(0.057)	(0.053)	(0.057)
Log Vehicles PC	0.256***	0.196	-0.521	-0.055	-0.124
	(0.047)	(0.420)	(0.618)	(0.517)	(0.609)
Governing Party	0.134**	0.023	0.025	0.027	0.021
	(0.053)	(0.041)	(0.040)	(0.035)	(0.038)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	Yes	Yes	Yes	Yes
Province-specific Linear Trends	No	No	Yes	Yes	Yes
Province-specific Quadratic Trends	No	No	No	Yes	Yes
Region by Year Fixed Effects	No	No	No	No	Yes

Notes: Each cell corresponds to a separate regression. Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively. Sample sizes are 797 for Hospitals Per 100K, Hospitals Beds Per 100K, Students Per Teacher, percent with college education, 400 for Physicians Per 100K; 636 for Percent High School, Vehicles Per Capita, and Unemployment Rate; and 877 for Family Physician Program, and Governing Party Affiliation.

Table 2B: Estimates of Natural Gas Intensity on Time Varying Observable Province Characteristics

Variable	(1)	(2)	(3)	(4)	(5)
Hospitals Per 100K	-0.748*	-0.189	-0.000	-0.050	-0.145
	(0.379)	(0.339)	(0.153)	(0.114)	(0.141)
Hospitals Beds Per 100K	0.012	-0.012*	-0.006*	0.002	0.002
	(0.007)	(0.007)	(0.004)	(0.002)	(0.002)
Physicians Per 100K	0.060***	-0.032**	-0.005	0.005	0.012
	(0.019)	(0.015)	(0.009)	(0.015)	(0.017)
Percent High School	0.891***	0.086	-0.128*	-0.010	0.004
	(0.260)	(0.118)	(0.074)	(0.062)	(0.088)
Percent College	1.334***	0.669***	0.041	0.062	0.166
	(0.374)	(0.180)	(0.114)	(0.100)	(0.139)
Students Per Teacher	-0.130	0.126**	0.109**	-0.002	-0.006
	(0.090)	(0.058)	(0.054)	(0.023)	(0.025)
Unemployment Rate	0.040	-0.141*	0.057	-0.005	-0.021
	(0.110)	(0.073)	(0.035)	(0.037)	(0.065)
Family Physician Program	1.051	0.467	-0.498	-0.041	0.055
	(1.497)	(0.508)	(0.377)	(0.296)	(0.305)
Log Vehicles PC	2.609***	-9.312	0.056	3.708	7.049
	(0.847)	(7.204)	(3.741)	(3.832)	(5.632)
Governing Party	0.925	-0.315	-0.257	0.048	0.138
	(1.182)	(0.518)	(0.296)	(0.136)	(0.176)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	Yes	Yes	Yes	Yes
Province-specific Linear Trends	No	No	Yes	Yes	Yes
Province-specific Quadratic Trends	No	No	No	Yes	Yes
Region by Year Fixed Effects	No	No	No	No	Yes

Notes: Each cell corresponds to a separate regression. Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively. Sample sizes are 797 for Hospitals Per 100K, Hospitals Beds Per 100K, Students Per Teacher, percent with college education, 400 for Physicians Per 100K; 636 for Percent High School, Vehicles Per Capita, and Unemployment Rate; and 877 for Family Physician Program, and Governing Party Affiliation.

Table 3A: Estimates of Any Natural Gas on Jointly Specified Time Varying Observable Province Characteristics

Variable	(1)	(2)	(3)	(4)	(5)
Hospitals Per-100 K	-0.078***	0.016	-0.012	-0.009	-0.021
	(0.027)	(0.028)	(0.021)	(0.020)	(0.019)
Hospital Beds Per-100 K	0.001	-0.001	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Physicians Per-100 K	0.001	0.001	0.001	0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Percent High School	0.032**	0.022*	0.019*	0.017	0.004
	(0.013)	(0.013)	(0.011)	(0.012)	(0.018)
Percent College	-0.013	-0.033	-0.010	0.004	-0.005
	(0.018)	(0.026)	(0.017)	(0.018)	(0.025)
Log Students Per Teacher	0.228	0.200*	0.122	0.093	0.052
	(0.137)	(0.112)	(0.093)	(0.123)	(0.142)
Unemployment Rate	-0.014**	-0.014**	-0.006	-0.004	0.006
	(0.007)	(0.006)	(0.006)	(0.005)	(0.009)
Family Doctor	-0.061	-0.010	-0.049	-0.032	-0.030
	(0.074)	(0.062)	(0.054)	(0.050)	(0.056)
Log MV Per 1000 People	0.210***	0.214***	-0.060	-0.080*	-0.030
	(0.060)	(0.061)	(0.059)	(0.045)	(0.068)
Governing Party	0.096**	0.010	0.028	0.035	0.022
	(0.042)	(0.042)	(0.040)	(0.039)	(0.039)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	Yes	Yes	Yes	Yes
Province-specific Linear Time Trends	No	No	Yes	Yes	Yes
Province-specific Quadratic Time Trends	No	No	No	Yes	Yes
Region by Year Fixed Effects	No	No	No	No	Yes
Observations	877	877	877	877	877
R-squared	0.466	0.528	0.720	0.805	0.842
F-test for Joint Significance	7.530	3.167	1.138	1.066	0.462
P-value	0.000	0.001	0.344	0.399	0.921

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Table 3B: Estimates of Natural Gas Intensity on Jointly Specified Time Varying Observable Province Characteristics

Variable	(1)	(2)	(3)	(4)	(5)
Hospitals Per-100 K	-0.735	0.578	0.018	-0.152	-0.218
	(0.492)	(0.385)	(0.184)	(0.209)	(0.256)
Hospital Beds Per-100 K	0.005	-0.020***	-0.006*	-0.003	-0.003
	(0.007)	(0.006)	(0.004)	(0.004)	(0.005)
Physicians Per-100 K	0.018**	0.010	0.001	0.000	0.000
	(0.009)	(0.006)	(0.003)	(0.002)	(0.003)
Percent High School	0.350	0.235*	-0.207**	-0.070	-0.097
	(0.293)	(0.137)	(0.087)	(0.045)	(0.094)
Percent College	0.912	0.308	0.432***	0.144	0.153
	(0.621)	(0.243)	(0.125)	(0.097)	(0.118)
Log Students Per Teacher	4.006	2.272**	1.895**	-0.783	-0.524
	(3.040)	(1.072)	(0.741)	(0.523)	(0.560)
Unemployment Rate	-0.047	-0.068	0.010	0.028	0.038
	(0.106)	(0.046)	(0.035)	(0.022)	(0.036)
Family Doctor	-0.652	0.055	-0.432	-0.021	0.095
	(1.105)	(0.482)	(0.376)	(0.284)	(0.294)
Log MV Per 1000 People	-0.129	0.030	-1.115***	-0.038	0.507
	(1.076)	(0.438)	(0.417)	(0.259)	(0.423)
Governing Party	0.738	-0.176	-0.278	0.074	0.192
	(1.079)	(0.474)	(0.288)	(0.146)	(0.186)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	Yes	Yes	Yes	Yes
Province-specific Linear Time Trends	No	No	Yes	Yes	Yes
Province-specific Quadratic Time Trends	No	No	No	Yes	Yes
Region by Year Fixed Effects	No	No	No	No	Yes
Observations	877	877	877	877	877
R-squared	0.477	0.531	0.886	0.944	0.951
F-test of Joint Significance	4.108	5.027	5.063	1.483	1.156
P-value	0.000	0.000	0.000	0.154	0.331

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Table 4A: Impact of Any Natural Gas on Logarithm of Infant Mortality Rate

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Any Natural Gas	0.490***	0.576***	-0.271**	-0.025	-0.032	-0.037	-0.126
	(0.105)	(0.124)	(0.113)	(0.103)	(0.113)	(0.115)	(0.115)
Hospitals Per-100 K						0.001	-0.008
						(0.050)	(0.060)
Hospital Beds Per-100 K						-0.000	0.000
						(0.001)	(0.001)
Physicians Per-100 K						0.000	0.000
						(0.001)	(0.001)
Log Per Capita Regional GDP						0.361	---
						(0.233)	
Percent High School						-0.016	0.012
						(0.024)	(0.032)
Percent College						0.022	-0.029
						(0.034)	(0.040)
Log Students Per Teacher						-0.032	0.060
						(0.348)	(0.374)
Unemployment Rate						0.003	0.014
						(0.015)	(0.018)
Family Doctor						0.012	-0.026
						(0.075)	(0.069)
Log MV Per 1000 People						-0.162	0.225
						(0.165)	(0.188)
Governing Party						-0.022	-0.010
						(0.066)	(0.067)
Observations	877	877	877	877	877	877	877
R-squared	0.065	0.096	0.145	0.436	0.572	0.577	0.637
Controls For							
Year Fixed Effects	--	X	X	X	X	X	X
Province Fixed Effects	--	--	X	X	X	X	X
Province-specific Linear Trends	--	--	--	X	X	X	X
Province-specific Quadratic Trends	--	--	--	--	X	X	X
Time Varying Province Characteristics	--	--	--	--	--	X	X
Region-by-year Fixed Effects	--	--	--	--	--	--	X

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 90%, 95%, or 99% levels, respectively. The measure of regional GDP is dropped from the specification that controls for region-by-year fixed effects.

Table 4B: Impact of Natural Gas Intensity on Logarithm of Infant Mortality Rate

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Natural Gas Intensity	0.016**	0.015*	-0.043***	-0.043***	-0.041**	-0.042**	-0.041**
	(0.007)	(0.008)	(0.009)	(0.015)	(0.017)	(0.017)	(0.020)
Any Natural Gas	0.366***	0.460***	-0.216**	-0.055	-0.044	-0.050	-0.143
	(0.088)	(0.097)	(0.098)	(0.100)	(0.111)	(0.114)	(0.115)
Hospitals Per-100 K						-0.006	-0.019
						(0.051)	(0.060)
Hospital Beds Per-100 K						-0.000	0.000
						(0.001)	(0.001)
Physicians Per-100 K						0.000	0.000
						(0.001)	(0.001)
Log Per Capita Regional GDP						0.332	--
						(0.231)	
Percent High School						-0.018	0.009
						(0.024)	(0.032)
Percent College						0.029	-0.019
						(0.034)	(0.040)
Log Students Per Teacher						-0.064	0.036
						(0.347)	(0.372)
Unemployment Rate						0.004	0.015
						(0.015)	(0.018)
Family Doctor						0.011	-0.022
						(0.075)	(0.071)
Log MV Per 1000 People						-0.154	0.232
						(0.164)	(0.188)
Governing Party						-0.018	-0.003
						(0.067)	(0.069)
Observations	877	877	877	877	877	877	877
R-squared	0.072	0.103	0.198	0.448	0.577	0.582	0.641
Controls For							
Year Fixed Effects	--	X	X	X	X	X	X
Province Fixed Effects	--	--	X	X	X	X	X
Province-specific Linear Trends	--	--	--	X	X	X	X
Province-specific Quadratic Trends	--	--	--	--	X	X	X
Time Varying Province Characteristics	--	--	--	--	--	X	X
Region-by-year Fixed Effects	--	--	--	--	--	--	X

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 90%, 95%, or 99% levels, respectively. The measure of regional GDP is dropped from the specification that controls for region-by-year fixed effects.

Table 5: Impact of Natural Gas Intensity on Infant Deaths and Births

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A							
Dependent Variable: Log Infant Deaths							
Natural Gas Intensity	0.000	-0.008	-0.047***	-0.044**	-0.050***	-0.051***	-0.051***
	(0.007)	(0.008)	(0.012)	(0.018)	(0.016)	(0.017)	(0.018)
Any Natural Gas	0.703***	0.289**	-0.172	0.023	0.013	0.009	-0.056
	(0.105)	(0.114)	(0.114)	(0.125)	(0.123)	(0.127)	(0.127)
Log Births	1.271***	1.348***	-0.076	1.707**	1.340*	1.102	0.933
	(0.054)	(0.052)	(0.346)	(0.661)	(0.740)	(0.743)	(0.828)
Panel B							
Dependent Variable: Log Infant Births							
Natural Gas Intensity	0.041*	0.043*	0.006**	0.000	0.001	0.001	0.001
	(0.023)	(0.022)	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)
Any Natural Gas	0.107	0.418***	0.016	0.010	0.007	0.006	0.003
	(0.125)	(0.148)	(0.021)	(0.009)	(0.007)	(0.007)	(0.009)
Observations	877	877	877	877	877	877	877
Controls For							
Year Fixed Effects	--	X	X	X	X	X	X
Province Fixed Effects	--	--	X	X	X	X	X
Province-specific Linear Trends	--	--	--	X	X	X	X
Province-specific Quadratic Trends	--	--	--	--	X	X	X
Time Varying Province Characteristics	--	--	--	--	--	X	X
Region-by-year Fixed Effects	--	--	--	--	--	--	X

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Table 6: Impact of Natural Gas Intensity on Logarithm of Infant Mortality Rate - Robustness Analyses with Alternative Subsamples

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: ***Natural Gas Sample***							
Natural Gas Intensity	0.016**	0.016**	-0.015	-0.016	-0.041**	-0.039**	-0.041*
	(0.007)	(0.007)	(0.010)	(0.016)	(0.017)	(0.018)	(0.021)
Any Natural Gas	0.099	0.379**	0.116	0.041	-0.016	-0.003	-0.090
	(0.089)	(0.145)	(0.089)	(0.096)	(0.112)	(0.114)	(0.117)
Observations	668	668	668	668	668	668	668
Panel B: ***Istanbul Excluded***							
Natural Gas Intensity	0.014	0.013	-0.041***	-0.044***	-0.042**	-0.043**	-0.042**
	(0.009)	(0.010)	(0.009)	(0.015)	(0.017)	(0.018)	(0.021)
Any Natural Gas	0.364***	0.446***	-0.231**	-0.059	-0.045	-0.051	-0.145
	(0.088)	(0.097)	(0.099)	(0.101)	(0.111)	(0.114)	(0.116)
Observations	866	866	866	866	866	866	866
Panel C: ***Ankara, Bursa, Eskisehir, Istanbul, and Kocaeli Excluded***							
Natural Gas Intensity	-0.016	-0.024	-0.036***	0.017	-0.045**	-0.046**	-0.046*
	(0.014)	(0.016)	(0.010)	(0.011)	(0.018)	(0.019)	(0.023)
Any Natural Gas	0.448***	0.472***	-0.270**	0.189*	0.042	-0.058	-0.145
	(0.092)	(0.104)	(0.107)	(0.103)	(0.107)	(0.116)	(0.115)
Observations	822	822	822	822	822	822	822
Controls For							
Year Fixed Effects	--	X	X	X	X	X	X
Province Fixed Effects	--	--	X	X	X	X	X
Province-specific Linear Trends	--	--	--	X	X	X	X
Province-specific Quadratic Trends	--	--	--	--	X	X	X
Time Varying Province Characteristics	--	--	--	--	--	X	X
Region-by-year Fixed Effects	--	--	--	--	--	--	X

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 90%, 95%, or 99% levels, respectively.

Table 7: Long Difference Estimates of the Impact of Natural Gas Intensity and Any Natural Gas on Logarithm of Infant Mortality Rate

Variable	(1)	(2)	(3)	(4)
	Just 2005 and 2001	Just 2007 and 2001	Just 2009 and 2001	Just 2011 and 2001
Panel A: ***Natural Gas Intensity***				
Natural Gas Intensity	-0.004	-0.013	-0.044***	-0.049***
	(0.021)	(0.014)	(0.011)	(0.011)
Panel B: ***Any Natural Gas***				
Any Natural Gas	0.174	-0.056	-0.442**	-0.816***
	(0.117)	(0.142)	(0.188)	(0.245)
Observations	154	158	160	158

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 90%, 95%, or 99% levels, respectively.

APPENDIX

The estimates from equation (3) would yield the reduced form impact of natural gas intensity on infant mortality rate. These estimates are novel and policy relevant in their own right. To explore the potential channel between the infant mortality rate and natural gas utilization, we also employ models using two-stage least squares (2SLS), in which a province level air pollution measure is instrumented on natural gas services subscription rate. In particular, we supplement our empirical framework with data on particulate matter (PM_{10}), which we obtained from the Turkish Ministry of Health.[28] Note that we have this measure only for the sub-period of 2002-2010 for an unbalanced panel. In particular, we have 490 year and province observations on particulate matter.[29] The descriptive statistics in Table 1 indicate that the average levels of particulate matter are lower in provinces that have accessed to a natural gas infrastructure at some point during our analysis period.

Note that an appropriate causal model for the impact of air pollution on infant mortality rate can be expressed as follows:

$$IMR_{pt} = X_{pt}\,\mu_1 + \mu_2\,PM_{pt} + \omega_p + \lambda_t + \varsigma_{pt}, \qquad \text{(A1)}$$

where PM_{pt} is natural logarithm of total particulate matter. In this model, μ_2 is interpreted as the impact of air pollution on infant mortality rate. Note that equation (3) accounts for permanent differences across provinces and nationwide trends through province-fixed effects and year fixed effects, respectively.

Next, suppose the relationship between air pollution and natural gas penetration rate is determined by the following first-stage equation:

[28] Air pollution measure is the averages computed at the province centers. In calculating annual averages, measurements are taken for a minimum of 21 days for each month for at least nine months.
[29] Most of the missing observations on pollution variables come from the period prior to 2007.

$$PM_{pt} = X_{pt}\,\pi_1 + \pi_2\,Natural\_Gas\_Intensity_{pt} + \omega_p + \lambda_t + \upsilon_{pt}. \quad (A2)$$

Equations (A1) and (A2) imply that the reduced form relationship between the natural gas penetration and infant mortality rate is as expressed in equation (3). Then the reduced form effect of natural gas penetration on infant mortality rate is $\beta_2 = \mu_2{*}\,\pi_2$. The causal effect of air pollution on infant mortality rate is then estimated using the instrumental variables method. The assumption underlying this approach is that the variation in *Natural Gas Intensity* is exogenous once we account for year and province fixed effects. Note that the validity of the instrumental variables hinges on the assumption that the expansion of natural gas networks can only affect infant mortality through its effect on air pollution once time-varying province characteristics and fixed effects are controlled for. This assumption would be violated if there are other factors, such as energy prices or other unmeasured air pollutants that are influenced by natural gas expansion. To the extent that these factors are not accounted for by our controls, the IV estimate would be biased. Therefore, we consider the IV estimates as suggestive, so caution must be exercised in interpreting them.

Panel A of the Appendix Table 4 presents evidence on the first stage relationship between particular matter and natural gas services subscription rate. The results from the first stage lend strong support to the hypothesis that the effects presented in this paper are driven by the improvements in air quality caused by the expansion of natural gas networks. In particular, the point estimate suggests that a one-percentage point increase in the natural gas services subscription rate is associated with a 4 percent decrease in level of particulate matter. Note that the sample size in these models is smaller due to lack of complete data on air pollution. Despite the smaller sample size, the estimate is statistically significant at conventional levels.

The instrumental variables estimates of the causal impact of air pollution on infant mortality rate are presented in Panel B of Appendix Table 4. As shown in the table, air pollution has a positive and statistically significant impact on infant mortality. The elasticity estimate for particulate matter is 1.113. We are also able to compare our elasticity estimate to those obtained in several previous studies. For example, our estimates are particularly consistent with those of Tanaka (2012), which reports an elasticity of 0.95 for particulate matter in a study of the impact of air pollution on infant mortality in China. Focusing on the estimates derived from the United State context, the elasticity estimates for particulate matter documented by Chay and Greenstone (2003a), Currie, Neidell, and Schmieder (2009), and Currie and Neidell (2005) are 0.285, -0.008, and 0.001, respectively.[30] In a recent study focusing on Mexico, Arceo-Gomez, Hanna, and Oliva (2012) find an elasticity of 0.42 for particulate matter, which is smaller than our estimate, but larger than those reported for the United States. To the extent that our estimates are larger than those reported by studies using data from the United States and consistent with those obtained for China, and to some extent, Mexico, the number of lives of infants saved due to improved air quality is likely to be higher in the developing countries than it is for the developed countries.[31]

[30] These figures are obtained from Table 8 in Arceo-Gomes, Hanna, and Oliva (2012).

[31] One exception is Knittel, Miller, and Sanders (2011) who find an effect corresponding to an elasticity of 1.88 studying the impact of air pollution on infant mortality in California.

Appendix Table 1: Natural Gas Adoption Year and Natural Gas Services Subscription Rate in 2011 for Provinces with at Natural Gas Infrastructure

Province	Adoption Year	Subscription Rate in 2011	Province	Adoption Year	Subscription Rate in 2011
Adana	2010	0.540	Karaman	2009	9.724
Adiyaman	2010	3.851	Kars	2009	1.153
Afyonkarahisar	2008	4.316	Kastamonu	2009	3.783
Aksaray	2006	11.067	Kayseri	2005	23.603
Amasya	2008	13.272	Kirikkale	2007	16.491
Ankara	1988	33.943	Kirklareli	2009	4.160
Antalya	2009	0.046	Kirsehir	2007	16.865
Balikesir	2005	17.334	Kocaeli/Izmit	1996	20.319
Bayburt	2009	10.918	Konya	2005	12.478
Bilecik	2007	26.038	Kutahya	2005	16.309
Bolu	2010	8.229	Malatya	2007	19.067
Burdur	2009	3.686	Manisa	2007	6.914
Bursa	1992	31.613	Mersin	2010	0.512
Canakkale	2007	12.565	Nevsehir	2009	6.696
Cankiri	2009	8.726	Nigde	2007	8.180
Corum	2005	14.606	Ordu	2009	2.515
Denizli	2007	12.404	Osmaniye	2011	0.473
Diyarbakir	2009	4.633	Rize	2009	10.310
Duzce	2006	16.089	Sakarya	2005	14.684
Edirne	2009	4.965	Samsun	2006	8.942
Elazig	2009	12.283	Sanliurfa	2008	3.069
Erzincan	2009	7.396	Sivas	2006	21.868
Erzurum	2005	8.884	Tekirdag	2005	10.523
Eskisehir	1996	38.569	Tokat	2009	3.631
Gaziantep	2008	2.262	Trabzon	2010	0.672
Hatay	2010	0.103	Usak	2006	9.910
Isparta	2009	5.141	Van	2008	1.838
Istanbul	1992	34.446	Yalova	2006	19.130
Izmir	2007	5.390	Yozgat	2007	8.685
Kahramanmaras	2007	4.097	Zonguldak	2006	9.346
Karabuk	2009	9.944			

Notes: Provinces without natural gas infrastructure in 2011 are Sirnak, Mus, Hakkari, Aydin, Ardahan, Mugla, Tunceli, Siirt, Batman, Gumushane, Sinop, Mardin, Kilis, Igdir, Artvin, Bingol, Giresun, Bartin, Bitlis, and Agri. In Ankara, Bursa, Eskisehir, Istanbul, and Kocaeli natural gas infrastructure was developed prior to 2001. Natural gas services subscription rate is expressed in per hundred populations.

Appendix Table 2: Infant Mortality Rate by Source

Year	World Health Organization	United Nations	Turkish Statistical Institute
2001	26.1	31	11.4
2002	24.2	29	10.8
2003	22.3	26	10.7
2004	20.5	24	9.5
2005	18.9	22	9.2
2006	17.4	20	8.9
2007	15.9	18	8.9
2008	14.7	16	8.9
2009	13.6	15	8
2010	12.5	14	7.8
2011	11.5	---	7.9

Sources: Turkish Statistical Institute;
World Health Organization: Child Mortality Estimates;
United Nations: The State of the World's Children.
Note: We do not have data on the infant mortality rate for 2011 from the United Nations.

Appendix Table 3: Weighted Estimates of Logarithm of Infant Mortality with Alternate Measures of Natural Gas

	(1)	(2)
Panel A: Mean Population Density Weighted Regressions		
Natural Gas Rate	-0.029**	
	(0.013)	
Any Natural Gas	-0.273**	-0.258*
	(0.134)	(0.134)
Panel B: Mean Birth Density Weighted Regressions		
Natural Gas Rate	-0.029**	
	(0.014)	
Any Natural Gas	-0.254**	-0.240**
	(0.120)	(0.120)
Observations	877	877
Controls For		
Year Fixed Effects	X	X
Province Fixed Effects	X	X
Region-by-year Fixed Effects	X	X
Province-specific Linear Trends	X	X
Province-specific Quadratic Trends	X	X
Time Varying Province Characteristics	X	X

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 90%, 95%, or 99% levels, respectively.

Appendix Table 4: Instrumental Variables Estimates of the Impact of Air Pollution on Infant Mortality and the Corresponding First Stage Estimates

Panel A: ***First Stage Estimates of the Impact of Natural Gas Rate on Air Pollution***

	Log Particulate Matter
Natural Gas Rate	-0.040***
	(0.013)
Any Natural Gas	-0.047
	(0.073)
Hospitals Per-100 K	-0.020
	(0.100)
Hospital Beds Per-100 K	0.001
	(0.001)
Physicians Per-100 K	-0.001
	(0.001)
Percent High School	-0.006
	(0.024)
Percent College	0.018
	(0.033)
Log Students Per Teacher	0.541
	(0.509)
Unemployment Rate	0.001
	(0.018)
Family Doctor	0.063
	(0.065)
Log MV Per 1000 People	0.132
	(0.155)
Governing Party	0.025
	(0.046)

Panel B: Second Stage Estimate of the Impact of Log Particulate Matter on Infant Mortality Rate

Log Particulate Matter	1.113**
	(0.555)
First Stage F-test	7.825
First Stage F-test (p-value)	0.007
Observations	490

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 90%, 95%, or 99% levels, respectively. In addition to province and year fixed effects, we also control for region by year fixed effects in the IV models.