The Stratified Effect of Extreme Temperatures on Birth Outcomes: The Role of Energy Prices

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Abstract

The effects of extreme temperatures on health at birth have been studied extensively in recent years. This study seeks to go a step further by examining how access to one of the mechanisms mothers use to protect themselves from extreme temperatures during pregnancy affects health at birth of the newborns. I focus on analyzing the affordability of sustained heating and air conditioning use during pregnancy, which depends in part on household energy prices. As identification strategy, I use a sharp increase in electricity and gas prices that occurred in Spain in March 2021 in interaction with weather conditions. In this way, I examine how the increase in energy prices affects birth outcomes through its impact on mothers' exposure to adverse weather conditions during pregnancy, differentiating by maternal vulnerability. I find that the impact of the increase on energy prices for mothers exposed to extreme temperatures during the third trimester of pregnancy on birth weight is greater among vulnerable mothers, particularly foreign mothers.

Key Words: Energy Price, Socioeconomic Status, Birth Weight, Extreme Temperatures.

1 Introduction

Events in utero have been shown to be crucial to the subsequent development of individuals. As explained in Almond and Currie (2011), the effects of conditions in utero are persistent, explaining from health outcomes later in life (Gluckman and Hanson, 2006) to educational performance and labor market prospects (Behrman and Rosenzweig, 2004).

A large body of literature has highlighted the importance of studying the effects of ambient temperature during pregnancy on birth outcomes (Agay-Shay et al., 2013; Auger et al., 2017; Chen et al., 2020; Cho, 2020; Conte Keivabu and Cozzani, 2022; Dadvand et al., 2011; Kloog et al., 2015; Strand, Barnett, and Tong, 2011; Strand, Barnett, and Tong, 2012). This paper aims to go a step further and examine one of the mechanisms by which this relationship can arise. Specifically, I examine how energy prices can mitigate the effects of extreme temperatures on health at birth as a function of maternal socioeconomic status. I argue that energy prices may have a moderating effect because they influence the affordability of heating and air conditioning when it is needed. Therefore, because of their influence on the affordability of using mechanisms that maintain indoor temperatures at appropriate levels, energy prices may act as a mechanism by which mothers can protect themselves from extreme temperatures during pregnancy.

Thus, with this study, I aim to fill two gaps in the literature on birth outcomes and extreme temperatures. First, previous literature has not studied how mothers can protect themselves from extreme temperatures during pregnancy. That is, they do not examine the context in which extreme temperatures play a more important role in birth health. I attempt to fill this gap by analyzing one of the potential protective mechanisms, the use of devices that maintain temperature at an appropriate level, which is determined in part by the price of energy consumed. Second, because this protective mechanism, which depends on energy prices, has not been studied before, the previous literature did not consider how these energy prices may affect protection from extreme temperatures differently depending on the socioeconomic status (SES) of the mother during pregnancy. That is, high-SES mothers are more likely to be able to protect themselves from extreme temperatures than low-SES mothers, who are more likely to suffer from energy poverty. For example, low-SES mothers are more likely to live in poorer neighborhoods where low-quality buildings are located. These low-quality buildings are less well thermally insulated and therefore offer less protection from extreme temperatures. In addition, mothers with high SES are more likely than mothers with low SES to protect themselves from extreme temperatures through heating systems in the cold winter and air conditioning in the hot summer, reflecting differences in mothers' purchasing power. Finally, mothers with high SES are more likely to work in places with air conditioning than mothers with low SES, who are more likely not to work or to work in places without air conditioning. I try to fill this gap by analyzing the differential impact of energy prices on birth outcomes as a function of maternal SES.

As case of study, I focus on Spain, where I exploit a sharp increase in energy prices in March 2021. Specifically, electricity prices in 2021 increased by about 250% and gas prices by about

526% in just nine months. Following Duflo (2001), I analyze how this increase affected health at birth depending on whether mothers faced extreme temperatures during pregnancy and their SES. Two things makes Spain specially suitable for studying this effect, first, because of the sharp increase in energy prices that this country has experienced in recent years. Second, the huge variability in temperatures between regions and seasons, which allows me to identify the effect of interest.

In summary, the objective of this study is to analyze the impact of energy prices on health at birth as a function of maternal socioeconomic status using the Spanish case study to test this theory. This analysis allows to better understand whether and for which socioeconomic groups extreme temperatures have the strongest impact on birth outcomes. This is particularly important in a process of global warming associated with rising energy prices and inequalities.

2 The Argument

2.1 Poverty and Energy Poverty

Poverty is one of the most important topics studied in the social sciences. Moreover, the impact of poverty on children's health is also of great importance (Fitzsimons et al., 2017; Green et al., 2018). In recent years, a new dimension of poverty has emerged: energy poverty. There are many different definitions of the concept of energy poverty, but they all refer to the minimum level of energy consumption required to satisfy some basic needs (González-Eguino, 2015; Reddy et al., 2000). Regarding the prevalence of energy poverty in Spain, the Ministry of Ecological Transition reports that the population affected by energy poverty in Spain ranges from 3.5 to 8.1 million people, depending on the energy poverty indicator used, which corresponds to between 7.4% and 17.1% of the population. In this section, I summarize the literature on energy poverty relevant to this study. First, I focus on the impact on the overall population and, second, I move to the impact on child outcomes.

In examining the impact of energy poverty on various outcomes in the overall population, Oliveras et al. (2021) find that energy poverty has increased during the crisis and that it is strongly associated with individual's health. They also conclude that this association was greater for individuals living in countries with high structural vulnerability. Pan, Biru, and Lettu (2021) study the impact of energy poverty on public health for 175 countries. Using multiple methodological analyses the authors find a consistent negative effect of energy poverty on public health. In addition, they analyze the possible channels through which this effect may operate and find that country living standards are an important channel. Davillas, Burlinson, and Liu (2022) analyze the impact of fuel shortages on the health and well-being of individuals. The authors define fuel shortages as the inability of a household to obtain a satisfactory level of energy services such as heat. They find a negative effect of fuel shortage on life satisfaction. However, this result varies significantly depending on the fuel poverty indicator studied. Prakash and Munyanyi (2021) find a significant positive association between energy poverty and the likelihood of becoming obese. They argue that the channels through which this occurs are the quality of sleep and the mental and general health of the individual. Finally, Thomson, Snell, and Bouzarovski (2017) analyze the relationship between energy poverty, health, and well-being in 32 European countries. The authors compare levels of health and well-being between households that are considered energy poor and those that are not within countries. They find that in countries with more equality, the differences in health and well-being between energy-poor and non-energy-poor individuals are greater than in countries with more inequality.

Regarding the impact of energy poverty on various outcomes in children, Mohan (2021) argues that children spend most of their time in their homes, and therefore the conditions in their homes are particularly important for their health. The author focuses on one of these housing characteristics, the affordability of an appropriate temperature in the home. She notes that not being able to maintain an adequate temperature in the home has a negative impact on the health of young children. However, it finds no significant effect for older children (at least 9 years old). Nawaz (2021) examines the effects of energy poverty and climate shocks on health using Pakistan as a case study. Using a multidimensional energy poverty index and an instrumental variable approach, she finds a negative effect of energy poverty and climate shock on maternal and child health. Similarly, Zhang, Appau, and Kodom (2021) examines the role that energy poverty plays in determining child well-being in the case of China. Again using a multidimensional poverty index and instrumental variable approach, the authors find a negative effect of energy poverty on children's well-being. They also find that an important channel for the estimated effect is school performance.

This evidence points out that energy poverty is a relevant issue with many consequences for the entire population in general and children in particular. However, even though scholars in sociology, medicine and economics fields have studied this relationship, the impact of energy poverty on health at birth has been overlooked. That is, to the best of my knowledge no research has been done on how energy accessibility can affect the health of the mother during pregnancy and consequently the health of the newborn. The next section explain how inadequate temperature affects the mother during pregnancy and, consequently, the fetus.

2.2 Extreme Temperatures and Birth Outcomes

Extreme temperatures have been associated with high mortality rates (Carmona et al., 2016; Lee et al., 2016) and various health problems such as respiratory and cardiovascular problems, increased blood and pulse pressure, and a higher likelihood of mental health problems and suicide (Hansen et al., 2008; Lanzinger et al., 2014; Carreras, Zanobetti, and Koutrakis, 2015; Dahlquist et al., 2016; Kim et al., 2016; Phung et al., 2016). In addition, a large body of literature has addressed the role that extreme temperatures play on birth outcomes. In this section, I first focus on a summary of this literature and then on the literature that analyzes the mechanisms by which extreme temperatures affect health at birth.

Agay-Shay et al. (2013) and Auger et al. (2017) examine the association between exposure to ambient temperatures during pregnancy and congenital heart defects in the offspring. While Agay-Shay et al. (2013) study the effects of maternal temperature exposure at weeks 3 to 8 of pregnancy, Auger et al. (2017) focus on the first trimester of pregnancy. Both conclude that deviations from normal temperature during pregnancy are significantly associated with the likelihood that their babies suffer congenital heart defects. Conte Keivabu and Cozzani (2022), Chen et al. (2020), and Deschênes, Greenstone, and Guryan (2009) examine the effects of extreme temperatures on birth weight. All of them conclude that exposure to extreme temperatures have a detrimental effect on birth weight. Conte Keivabu and Cozzani (2022) find more adverse effects when exposure occurs in early pregnancy and in mothers with low SES. Deschênes, Greenstone, and Guryan (2009) emphasize that the strongest impact occurs in the second and third trimesters of pregnancy, while Chen et al. (2020) highlight that lack of access to mechanisms to keep temperatures at appropriate levels may be one of the main causes of the negative effects mentioned.

On the question of how exposure to extreme temperatures during pregnancy affects preterm birth, the conclusions of Strand, Barnett, and Tong, 2011; Strand, Barnett, and Tong, 2012, and Cho (2020) diverge. Strand, Barnett, and Tong (2011) review the existing literature and conclude that ambient temperature has a significant effect on preterm birth, but note that the effect is greater for birth weight than for preterm birth. Strand, Barnett, and Tong (2012), using a Cox proportional hazard model, conclude that increased temperatures during the third trimester of pregnancy increase the likelihood of experiencing preterm birth and stillbirth. However, Cho (2020) concludes that the effects of temperature changes during pregnancy do not significantly affect preterm birth or low birth weight. Finally, Dadvand et al. (2011) and Kloog et al. (2015) study how extreme temperatures affect gestational age. Both conclude that extreme temperatures negatively affect gestational age. However, Dadvand et al. (2011) focus on short-term exposures to extreme temperatures, whereas Kloog et al. (2015) focuses on longer exposures.

Regarding the biological mechanisms by which extreme temperatures affect health at birth, there are no clear conclusions in the literature. Some authors argue that pregnant women experience more heat stress because they accumulate more fat during pregnancy and the body surface area to body mass ratio decreases as a result of weight gain (Wells and Cole, 2002; Wells, 2002; Dadvand et al., 2011; Strand, Barnett, and Tong, 2011; Agay-Shay et al., 2013; Lin et al., 2017). In addition, some argue that it may be more difficult for pregnant women to sleep in unusual temperatures and that poor sleep is associated with health problems at the time of delivery (Okun et al., 2009; Strand, Barnett, and Tong, 2011; Lin et al., 2017). In contrast, Auger et al. (2017) argue that high temperatures during pregnancy can lead to fetal cell death, which in turn can affect the health of the newborn. The authors also argue that extremely hot temperatures can cause placental insufficiency, which impairs fetal development in utero. Finally, Deschênes, Greenstone, and Guryan (2009) propose fetal nutrient intake as a mechanism linking heat and cold stress during pregnancy to health at the time of birth.

In summary, although there is no clear conclusion on the biological mechanism by which extreme temperatures affect birth outcomes, previous literature has found that extreme temperatures during pregnancy can negatively affect birth outcomes such as congenital heart defects, birth weight, and preterm birth. However, they have not analyzed the mechanisms by which mothers may be affected by extreme temperatures during pregnancy. I try to fill this gap by focusing on one of these mechanisms, energy prices, as they affect the affordability of using devices that maintain indoor temperatures at an adequate level. Moreover, I analyze how the moderating effect that energy prices may have on health at birth varies by household socioeconomic status.

2.3 Energy Prices, Extreme Temperatures and Birth Outcomes: Hypotheses

As explained in the previous sections, the main objective of this study is to fill a gap in the literature by analyzing one of the mechanisms by which mothers can protect themselves from extreme temperatures during pregnancy and how this affects health at birth.[1] I focus on energy prices and argue that they may matter because they affect the affordability of heating during cold spells and air conditioning during heat spells. In addition, energy prices are likely to be more decisive when mothers suffer from adverse weather conditions during pregnancy, i.e., the increase in energy prices could have a greater impact on homes thermal regulation when weather conditions worsen. Therefore, I argue that energy prices have an interactive effect with the weather conditions that mothers face during pregnancy. Thus, I expect that extreme temperatures during pregnancy affect birth outcomes differently depending on the energy prices that mothers face.

Hypothesis 1: *Exposure to adverse weather conditions during pregnancy affect birth weight more negatively when energy prices are high.*

I also investigate the differential effect that energy prices might have on birth outcomes depending on the socioeconomic status of the household. I expect the impact to be larger for newborns from households with lower socioeconomic status. This is because I expect families with lower socioeconomic status to have more difficulty regulating temperature in their homes when energy prices rise than families with higher socioeconomic status. Since information on the mother's SES is not yet available, I distinguish by characteristics of mothers that increase the likelihood of having low SES. That is, I consider a mother to be vulnerable from suffering from low SES if she is unmarried or foreigner.

[1]I use birth weight as the main measure of health at birth, following previous literature (Almond and Currie, 2011; Gluckman and Hanson, 2006; Conley and Bennett, 2000; Behrman and Rosenzweig, 2004; Almond, Hoynes, and Schanzenbach, 2011; Brown, 2018; Bharadwaj, Johnsen, and Løken, 2014). However, other measures commonly used in the literature, such as weeks of gestation, low birth weight, and preterm birth, are analyzed in the Appendix

Hypothesis 2: *Exposure to adverse weather conditions when during pregnancy when energy prices are high has a greater negative effect on birth weight in vulnerable mothers.*

3 The Case of Spain

3.1 Energy Market in Spain

In the Spanish electricity market, there are three types of tariffs that households can contract (Fabra et al., 2021). First, at default rates, where households can buy electricity at the *Voluntary Price for the Small Consumer*. This type of contract sets a variable energy price that is determined daily by the government depending on the price of electricity in the wholesale electricity market. In this type of contract, the price of electricity changes hourly. Second, the retail market, where companies compete with each other and each of them can set the price it offers to individual consumers. This price does not change over time and is set by contract on an individual basis. And third, direct access to the wholesale market. Although households can buy electricity in this way, they do not do so because of the high transaction costs involved. As reported by the regulatory body, the *Comisión Nacional de los Mercados y la Competencia* (CNMC), in the first trimester of 2021, 62.5% of households were buyers of electricity at the default rate, while 37.5% of them are buyers in the retail market. It can be argued that households' decisions regarding their electricity consumption may change depending on the electricity tariffs they purchase. However, as reported by CNMC using survey data for the second trimester of 2021, only three out of ten households know the difference between the tariffs at the default rate and tariffs of the retail market. Furthermore, Fabra et al. (2021) shows that the observable characteristics of households that report knowing the difference between the tariffs and those that do not are, on average, the same. From this, I conclude that it does not matter what type of tariff individuals have, their response to the increase in electricity prices is likely to be the same.

As for the gas market, two types of tariffs exists. First, the default rates, where prices are set by the government through a public auction, similar to default rates in the electricity market. The price for this type of tariff changes every three months. Second, the retail market, where retail companies set the price for the tariff. Again using information reported by CNMC in the first trimester of 2021, 80.1% of households are buyers of gas at the default rate, while 19.9% are buyers in the retail market. However, as with electricity, individual households' decisions regarding their gas consumption do not seem to be influenced by the type of tariff. Using the same survey data as for electricity, only 22.7% of households confirm that they are aware of the different types of gas tariffs available to them.

3.2 Energy Access and Energy Usage for the Case of Spain

When analyzing the possibility of using heating and air conditioning, two characteristics should be considered. First, energy access, i.e., whether people have access to safe and modern energy supplies such as heaters and air conditioners. Second, energy use, i.e., whether people not only have heaters and air conditioners available but can afford to use them on a sustained basis. In this section, I present evidence on the percentage of households with energy access and energy use.

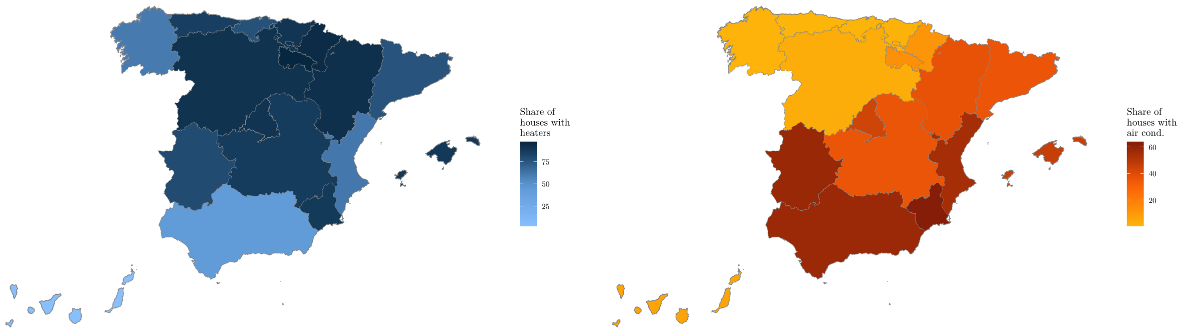
First, regarding access to energy, in Spain the percentage of the population with access to electricity (needed for the use of air conditioners and some types of heaters) and to fuels and technologies for cooking (needed for the use of other types of heaters) is 100% from the first year for which data are available (The World Bank, 2021b; The World Bank, 2021a).[2]As additional evidence, Figure 1 shows the percentage of households in Spain that have heaters (left map) and air conditioners (right map) at the NUTS 2 level. The left map shows that regions in the north have a larger percentage of heaters (in most cases, more than 80% of households have heaters) than regions in the south. This makes sense because the weather is colder in the north than in the south. For example, the average temperature in January for the years 1981 to 2010 in Leon (a city in northern Spain) is 3.2°C, while in Malaga (a city in the south) it is 12.1°C. Thus, the lower percentage of households in the south that have heating does not affect access to energy, since this type of equipment is usually not needed in these areas. The map to the right shows that the regions with a higher percentage of air conditioning are in the South (with a percentage of households with air conditioning of about 60% in most cases). Again, this makes sense considering that summer temperatures are more extreme in southern Spain. For example, the average temperature in August is 19.6°C in Leon and 26°C in Malaga. Again, the low percentage of households in the north that have air conditioning does not affect access to energy, since it is not normally needed in this part of the country. All of this suggests that access to energy is virtually guaranteed in Spain, at least since the beginning of the 21st century.

[FIGURE 1 HERE]

Second, energy use which depends on whether it is affordable to use heating and air conditioning in a sustained manner when it is needed, is not fully guaranteed in Spain, which is why I focus on it in this paper. That is, I investigate whether mothers can afford to use energy to heat or cool their homes during pregnancy and how this affects health at birth. One of the reasons for limiting the use of heat modulators is the associated energy costs, which at the same time depend on the price of energy for households. In this paper, I use as identification strategy a sharp increase in electricity and gas prices in Spain in March 2021, as shown in Figure 2 (dark gray line in each of the graphs). Specifically, electricity prices increased by about 250% and gas

[2]Data are available from 1990 for the case of electricity and from 2000 for the case of fuels and technologies for cooking.

Figure 1: Share of Households with Heaters and Air Conditioners.

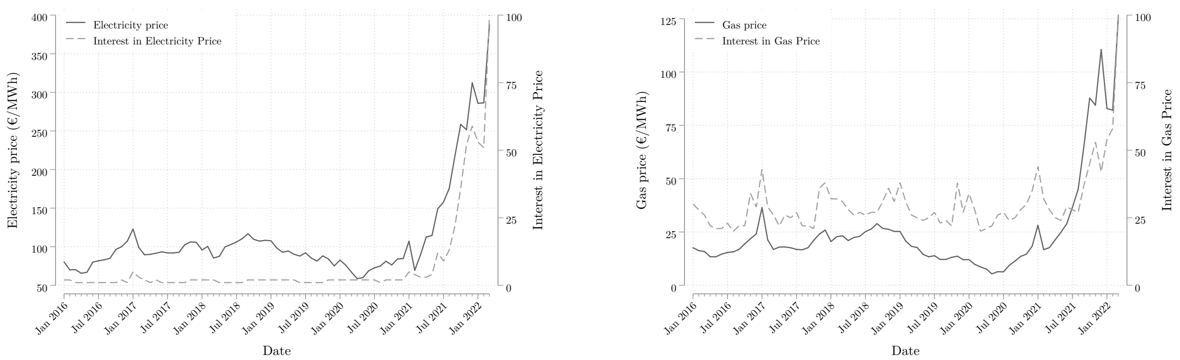


Notes: The map on the left shows the percentage of households with heaters at the NUTS 2 level in 2008. The map on the right shows the percentage of households with air conditioners at the Nuts 2 level in 2008. *Source:* Instituto Nacional de Estadística: Encuesta de Hogares y Medio Ambiente 2008.

prices increased by about 526% from March to December 2021, an unprecedented increase in Spain.

[FIGURE 2 HERE]

Figure 2: Electricity and Gas Prices and Google Trends of Interest in Them



Notes: The dark grey line shows the evolution over time of electricity prices (left graph) and gas prices (right graph) in Spain. *Sources:* Red Eléctrica de España (left graph) and Mercado Ibérico del Gas (right graph). The dashed light grey line indicates how frequently the terms "electricity price" term (left graph) and "gas price" (right graph) are entered into the Google search engine, relative to the total Google search volume for that term from 2016 to the end of 2021 for Spain. A value of 100 indicates the maximum popularity of the term. *Source:* Google Trends.

One potential concern would be that citizens are uninformed or underinformed about the price of energy. In this case, they would not change their consumption behavior in response to energy prices. The dashed lines in both graphs in Figure 2 show the Google trends of electricity price (left graph) and gas price (right graph), i.e., proxies of the interest people show in the terms "electricity price" and "gas price". This trend shows how often the terms "electricity price" and "gas price" are entered into the Google search engine, relative to the total Google search volume for that term, with a value of 100 indicating the maximum popularity of the term. From this figure, it can be seen that both energy prices themselves and the popularity of the above terms on Google follow the same trends, i.e., when prices increase, the popularity of searches for electricity and gas prices on Google also increases. This suggests that people are aware of energy prices (or at least the rise in these prices) and that they are informed about them when making decisions.

4 Data and Variables

This section describes the various data sources used in this study. I use a database of births from which I take the outcome variable (birth weight) and various characteristics of the newborns and their parents. I also use weather data at the daily level and data on various characteristics of the municipalities where the children are born. I then explain the procedure for creating the sample of the dataset. Finally, I present the summary statistics of the variables. Note that the unit of analysis is universe of births that occurred in Spain between 2016 and 2021.[3]

4.1 Sources and Definitions

This section explains the various data sources used for the analysis. The time span is from 2016 to 2021 for all analyses conducted in this study. I use birth weight as the main outcome variable, which is a good indicator of neonatal health (Conley and Bennett, 2000; Behrman and Rosenzweig, 2004; Gluckman and Hanson, 2006; Almond and Currie, 2011; Almond, Hoynes, and Schanzenbach, 2011; Bharadwaj, Johnsen, and Løken, 2014; Brown, 2018). These data come from the *Instituto Nacional de Estadística*. It is a very large dataset that contains information on all births that occurred in Spain between 2016 and 2021, organized by month and municipality.[4] In addition to variables on the health status of newborns at birth, this database contains information on various characteristics of newborns, such as gender and mothers, such as age, marital status, number of children considering this delivery, number of newborns at this birth, and nationality. Maternal marital status is divided into married and unmarried mothers. The number of children considering this delivery variable takes the value of one if it is the mother's first delivery and zero if it is not. The number of newborns in this delivery variable takes value one if it is a singleton birth and zero if it is a multiple birth. Finally, nationality is categorized as native or foreign.

[3]For data consistency, the first year studied is 2016, since the classification of parents' education and occupation in the database of births changed from that year onward.

[4]There are 8131 municipalities in Spain, but I only use data from the municipalities with more than 10,000 inhabitants that are available in the dataset on births. Therefore, the dataset contains information on births from 768 municipalities, corresponding to 86% of births in the sample years

The data on electricity prices come from the dataset *Red Eléctrica de España*. It contains data on "hourly voluntary electricity prices for the small consumer" in Spain in euros per megawatt-hour (MWh). As explained in an earlier section, it contains information on hourly electricity prices, which are set daily by the government depending on the price of electricity in the wholesale electricity market. The data on gas prices come from the *Mercado Ibérico del Gas* dataset. It contains data on the daily gas price in Spain in euros per MWh. Specifically, it is the average weighted price of all trades made in a trading session for daily gas in the Spanish zone.

I also control for weather data because the increase in energy prices could have a greater impact on the thermoregulation of households where pregnant women live when weather conditions are worse, for example due to a sharp drop in temperature. I use weather data obtained from a variety of sources. The basic data source is the *Agencia Estatal de Meteorología*. It contains daily data on several weather characteristics from all state-owned monitoring stations in Spain from 2016 to 2021. However, some Spanish provinces have additional weather stations from which I can obtain more accurate weather data.[5] Therefore, I use weather data from each state when available, and I use data from the *Agencia Estatal de Meteorología* for those states that do not have more detailed weather data for the entire study period. All data sources include daily data on various weather characteristics organized by weather monitors from 2016 to 2021.[6] In this project, the daily average temperature is used. Figure 3 shows a map with the locations of all the weather stations in Spain used for the analysis, as well as all the municipality centers with more than 10,000 inhabitants where at least one birth occurred during the analyzed period.

[FIGURE 3 HERE]

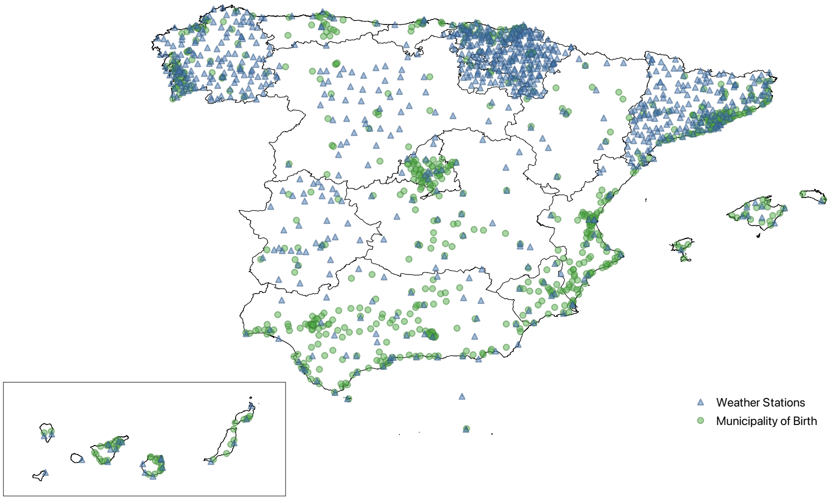
Finally, I include variables at the municipality level to avoid biased results. First, I include municipality-level employment characteristics because, as shown in Aparicio, Gonzalez, and Castelló (2020), the likelihood of negative birth outcomes decreases when unemployment increases, so the results could be biased if they are not taken into account.[7] Specifically, I control for population by municipality and year, which comes from the *Instituto Nacional de Estadística*, and unemployment, which comes from the *Servicio Público de Empleo Estatal*, which contains data on registered unemployment by municipality and month. Second, I consider municipality-level fertility to control for unobserved municipality-level characteristics that lead individuals to decide whether or not to have children. Specifically, I control for the number of births by municipality and month, which comes from the *Instituto Nacional de Estadística*. Last, I control

[5] Provinces are Nuts-3 level regions. Spain is composed of 52 provinces.

[6] States from which weather data are obtained from the *Agencia Estatal de Meteorología* are: Analucía, Aragón, Asturias, Illes Balears, Islas Canarias, Cantabria, Castilla la Mancha, Comunidad de Madrid, Comunitat Valenciana, Ceuta, and Melilla. The states from which the weather data come from its own sources of data are: Castilla y Leon, Catalunya, Extremadura, Galicia, La Rioja, Navarra, and País Vasco.

[7] They argue that part of this countercyclical behavior can be explained by the fact that there are fewer first births and fewer births to unmarried and younger parents, who tend to have fewer healthy babies.

Figure 3: Map of Weather Monitors and Municipalities of Birth in Spain



Notes: Data on weather monitors come from the *Agencia Estatal de Meteorología* or from the official data sources of each state government in Spain. This figure is plotted using QGIS.

for the COVID incidence by province and month. This is done to control for the entire period of pregnancy, how the COVID incidence affected from the decision to have a child to the time of delivery. Thus, individuals may have postponed their decision to have children because, for example, COVID affected the quality of their hospitals or their job security. In addition, it may be that the health of the newborn was affected by the lower quality or number of medical revisions during pregnancy due to hospital congestion during the pandemic. Specifically, I control for the number of hospitalizations by province and month obtained from the *Red Nacional de Vigilancia Epidemiológica*.

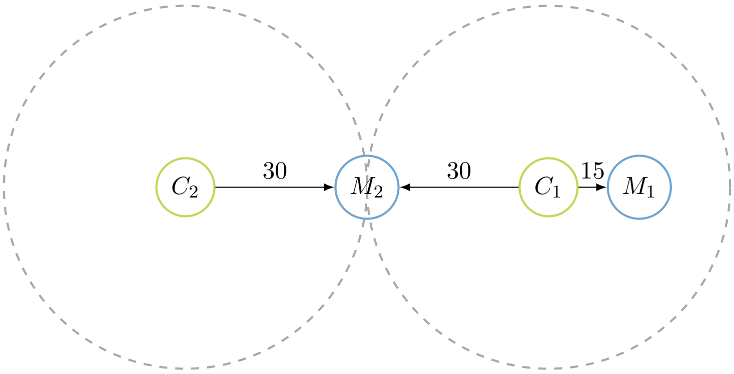
4.2 Sample Construction

As mentioned above, the unit of analysis is the universe of births in Spain from 2016 to 2021, by municipality and month. The data on energy prices apply to the entire country, but vary over time. Therefore, they apply to all births that occur during the same period. Weather data change over time and by municipality. Also, it can be seen from Figure 3 that the monitors are sparsely distributed in some regions, while there is a large overlap between them in other regions. To see how I deal with this situation, I turn to explain how the information is transferred from these monitors to the municipalities.

Using daily data from each of the weather variables considered, and following Neidell (2004) and Currie and Neidell (2005), I have elaborated a measure of weather by municipality.[8] This

[8]Note that Neidell (2004) and Currie and Neidell (2005) follow these steps to create a measure of pollution by zip code, but I use them to construct a measure of weather by municipality.

Figure 4: Graphical example of distance between centroids and weather monitors.



Notes: C_1: Centroid of municipality 1, C_2: Centroid of municipality 2, M_1: Weather monitor 1, M_2: Weather monitor 2. The dashed grey lines represent the radius from the centroid of each municipality, set as the maximum distance from the monitor to the centroid to include that monitor.

measure is created in two steps. First, I calculate the distance between the centroid of each municipality and each weather monitor using the coordinates of each monitor and the centroid.[9] Second, I construct the weighted hourly level of the mean temperature variable by municipality using all monitors within a 30 km radius from the municipalities's centroid, using as weight the inverse of the distance of each monitor to the centroid of the municipality. [10] Using these weights is useful because the monitors near the centroid of each municipality take more importance than those farther away. Figure 4 shows a simple illustrative example where C_1 and C_2 represent the centroids of municipalities 1 and 2, respectively; M_1 and M_2 represent weather monitors 1 and 2, respectively; and the dashed gray lines represent the radius of 30 km from the centroid of each municipality, which was set as the maximum monitor distance from the centroid to account for that monitor. Thus, the measure of daily average temperature for municipality 1, with centroid C_1, is constructed using both monitors M_1 and M_2. In this case, the daily average temperature measured in M_1 has more weight in the aggregate measure by municipality than the one measured in M_2, since M_1 is closer to C_1 than M_2. However, in the case of municipality 2, which is centered on C_2, only the daily average temperature measured in M_2 is considered, giving this monitor a weight of one.

[FIGURE 4 HERE]

In order to perform the analysis explained in the following section, I divide the municipalities by month into those with unfavorable and those with favorable weather conditions. To do this, I use a similar procedure as in Agay-Shay et al. (2013) and Dadvand et al. (2011). First, I divide the data into cold and hot seasons. The hot season goes from April to September and the cold season includes the months from October to March. Second, I divide the municipalities by

[9]Remember that only municipalities with populations greater than 10,000 are used.
[10]I use different radius values as a robustness tests in the Appendix.

the climatic area to which each of them belongs during the hot and cold seasons. The climatic areas are classified according to the degrees of temperature and the number of hours of sunshine that each municipality has. In Spain, there are five climatic areas in the cold season and four climatic areas in the hot season. Third, I look for extreme temperature events. A municipality is classified as having extreme heat on a day in the hot season if the mean daily temperature is above the 90th percentile, considering all the historical series available for the hot period in the climatic area to which it refers. Similarly, a municipality is classified as an extreme cold event on a day in the cold season if the mean daily temperature is below the 10th percentile of the historical series for the cold period in the climatic area to which it refers.[11] Fourth, for each trimester of pregnancy, I calculate the number of days that the municipality in which each mother lives was classified as having extreme temperatures. Finally, I classify mothers according to whether they suffered from extreme temperatures in each trimester of pregnancy. I define being exposed to extreme temperatures in each trimester of pregnancy if the number of days with extreme temperatures is greater than 8 on monthly average, so that about 10 percent of mothers are affected.

Recall that the goal of this paper is to examine how energy prices affect birth outcomes differently depending on the socioeconomic status (SES) of parents. However, because data on socioeconomic status are not yet available, I use data on maternal vulnerability. That is, I categorize mothers as vulnerable if they are unmarried or foreign-born, and otherwise as not vulnerable. I also create a measure of net job creation, where net job creation is defined as the difference between jobs created and jobs destroyed relative to the population by municipality and month. Because several independent variables that vary over time (weather variables, employment characteristics, and COVID incidence) can affect fetal health throughout pregnancy, not just at the time of delivery, I aggregate the data for these variables by trimester of pregnancy. That is, for each delivery, I construct a measure of each of the above variables for each trimester of pregnancy by averaging over the months of a trimester, taking into account the number of weeks of gestation for each mother.

4.3 Summary Statistics

[TABLE 1 HERE]

Table 1 shows the summary statistics for all variables used in the analysis. As for the main dependent variable, birth weight, the weight at the time of birth is measured in grams. The average weight of newborns during the analyzed period is approximately 3200. I restricted the sample to newborns weighing between 500 and 5000 grams because values below and above this range are likely to be infeasible births or coding errors. The distribution of birth weight is shown in Figure 5.

[11] Other percentiles are used to classify extreme temperature days in the Appendix as a robustness check.

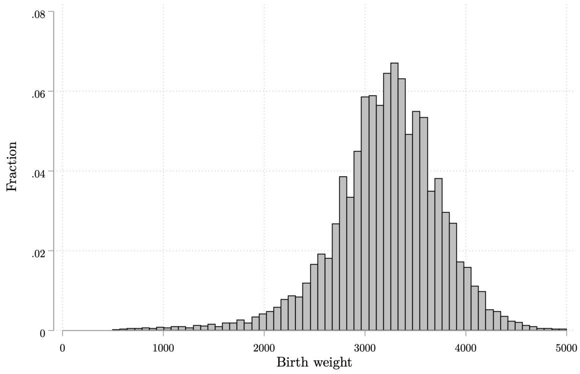
Table 1: Summary Statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Birth Weight	3215.758	537.107	500	5000	1,813,666
Extrem temp.: 1st Trim. (T1: ExtrT)	0.120	-	0.000	1.000	1,450,706
Extrem temp.: 2nd Trim. (T2: ExtrT)	0.115	-	0.000	1.000	1,531,779
Extrem temp.: 3rd Trim. (T3: ExtrT)	0.105	-	0.000	1.000	1,604,725
After: 1st Trim. (T1: After)	0.043	-	0.000	1.000	1,906,168
After: 2nd Trim. (T2: After)	0.081	-	0.000	1.000	1,906,168
After: 3rd Trim. (T3: After)	0.130	-	0.000	1.000	1,906,168
Male	0.514	-	0.000	1.000	1,906,168
Married	0.521	-	0.000	1.000	1,906,168
First Child	0.483	-	0.000	1.000	1,906,168
Singleton	0.962	-	0.000	1.000	1,906,168
Foreign	0.214	-	0.000	1.000	1,906,168
Age	32.669	5.674	12	61	1,906,168
Number of Births	365.264	683.502	1.000	2773	1,906,168
Net Job Creation: 1st trim.	-0.041	0.034	-0.197	0.314	1,479,708
Net Job Creation: 2nd trim.	-0.041	0.034	-0.197	0.314	1,562,260
Net Job Creation: 3rd trim.	-0.040	0.034	-0.197	0.333	1,637,642
COVID Incidence: 1st trim.	298.137	1269.595	0.000	12962.667	1,906,168
COVID Incidence: 2nd trim.	334.466	1326.788	0.000	12962.667	1,906,168
COVID Incidence: 3rd trim.	328.076	1221.814	0.000	26982	1,906,168

Notes: The summary statistics of the variables of the sample used in the analysis are displayed. In the second column of the table the mean of each variable is displayed. The third column shows the standard deviation. The fourth and fifth columns report the minimum and maximum values of each variable, respectively. The last column present the total number of observations available for each of the variables analyzed.

[FIGURE 5 HERE]

Figure 5: Distribution of Birth Weight in Grams

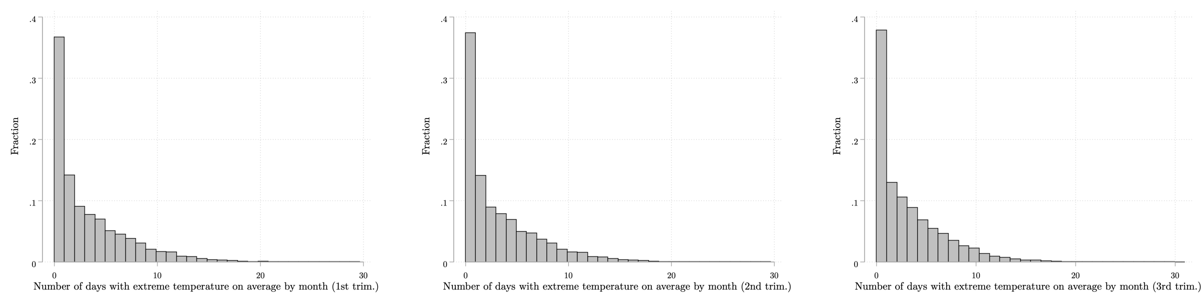


Extreme temp.: 1st Trim. indicates the percentage of mothers who lived in a municipality with extreme temperatures during the first trimester of pregnancy. The same is true for the second and third trimester variables. As it is shown around 11 percent of mothers suffered from extreme temperatures during each trimester of pregnancy. This means that about 11 percent of mothers suffered from extreme temperatures on a monthly average of at least 8 days in each trimester of pregnancy. Figure 6 shows the distribution of the number of days with extreme temperatures on a monthly average that mothers suffered during each trimester of pregnancy. As it is shown the distribution is right skewed for the three trimesters, indicating that the majority of mothers did not suffer from extreme temperatures during pregnancy.

[FIGURE 6 HERE]

Figure 6: Number of Extreme Temperature Days

(a) 1st trimester (b) 2nd trimester (c) 3rd trimester



Notes: The graph on the left shows the distribution of the number of days of extreme temperature in the monthly average suffered by mothers in the first trimester of pregnancy. The graphs in the middle and on the left show the same, but for the second and third trimesters of pregnancy, respectively.

The mean of the after variable for the first trimester of pregnancy shows the percentage of pregnancies in which the first trimester of pregnancy occurred after the increase in energy prices.

The same is true for the second and third pregnancy trimesters. That is, the mean of the after variable for the second (third) pregnancy trimester represents the percentage of pregnancies for which the second (third) trimester of pregnancy occurred after March 2021. Regarding the control variables, in the full sample, about half of the newborns are male. Similarly, about half of the mothers are married and half of the newborns are the mother's first child; 96% of the newborns are singleton, 20% of the mothers are foreigners, and the average age of the mothers in the sample is 32 years. Regarding the municipality-level variables, the average number of births per month per municipality is 365, and the net job creation over the population of each municipality is about -0.04 each trimester of pregnancy, indicating that more jobs were destroyed than created during the sample period. The COVID incidence variables refer to the number of hospitalizations due to COVID on average per month and municipality depending on the trimester of pregnancy. On average, there were about 300 hospitalizations due to COVID per month and municipality, but the standard deviation is large because there were no hospitalizations due to COVID in the early years of the sample.

5 Methodology

To determine the causal effect that energy price has on birth outcomes, differentiated by maternal vulnerability, I follow the analysis conducted in Duflo (2001). In this paper, the author uses differences across regions and differences across birth cohorts due to a shock to find the causal effect analyzed. The proposed benchmark model is as follows:

$$O_{ijt} = \alpha + \sum_{q=1}^{3}(P_{qjt} \times T_{qi}\beta_q + P_{qjt}\eta_q + T_{qi}\phi_q + U_{qjt}\pi_q) + X_{it}\lambda + W_{jt}\sigma + \gamma_j + \delta_t + \epsilon_{ijt} \qquad (1)$$

Here, O_{ijt} refers to the outcome variable under consideration (birth weight) of the newborn i, in municipality j and date of birth t. P_{qjt} is a dummy that takes value one if the mother belongs to a municipality with adverse weather conditions during the qth trimester of pregnancy, and a value zero if the individual belongs to a municipality without adverse weather conditions during this trimester of pregnancy. That is, P_{1jt} takes value one if the municipality where the mother lives experienced a monthly average of at least eight days of bad weather during the first trimester of pregnancy, and zero otherwise. The same is true for P_{2jt}, P_{3jt} for the second and third trimesters, respectively. T_{qi} is a dummy variable that takes value one if the individual received treatment during the qth trimester of pregnancy. Specifically, T_{1i} indicates whether the mother of the newborn i was in the first trimester of pregnancy after March 2021, the date of the increase in energy prices. The same is true for T_{2i} and T_{3i} in the second and third trimesters of pregnancy, respectively. U_{qjt} refers to the vector of municipality-level variables that may affect birth weight differently depending on the pregnancy trimester. That is, it includes net job creation and COVID incidence, defined in the previous section by trimester of pregnancy q, municipality j, and birth date t.

X_{it} is a vector containing various characteristics of the newborn and mother: gender of the newborn, age, marital status, number of children considering this delivery, number of newborns at this delivery, and nationality of the mother. W_{jt} refers to the number of births by municipality j and birth month t. γ_j refers to municipality fixed effects and δ_t to date of conception fixed effects by year-month. Finally, ϵ_{ijt} is the normally distributed error term. Thus, the coefficients of interest are β_1, β_2, and β_3, which indicate the estimated effects of exposure to adverse weather conditions during pregnancy on birth weight when the energy price increases in the first, second, and third trimesters of pregnancy, respectively. Intuitively, β_1 captures the effect of suffering from extreme temperatures during the first trimester of pregnancy on birth weight when energy prices are high. The same applies for β_2 during the second trimester of pregnancy and for β_3 during the third trimester of pregnancy.

To examine the differential effects of energy prices on birth outcomes as a function of maternal vulnerability, I regress Equation 1 separately by characteristics indicative of maternal vulnerability. In particular, I regress this equation separately depending on whether a mother is unmarried or married and whether she is foreign or not.

6 Results

Table 2 shows the results of OLS estimation of Equation 1. In the first four columns, the results represent the effect of exposure to extreme temperatures during each trimester of pregnancy on birth weight. In the last four columns, the interaction term between exposure to the increase in energy prices (March, 2021) for each trimester of pregnancy and exposure to extreme temperatures during each trimester of pregnancy is added. In the 1st and 5th columns, I include as a control variable only a dummy variable for the pregnancy trimester indicating whether the mother was before or after the increase in energy prices in each trimester of pregnancy. In the 2nd and 6th columns, I include individual-level demographic characteristics and municipality- and province-level variables that vary over time (Dem., Munic. & Prov.). That is, in these columns I include the mother's age, dummies for the sex of the newborn, whether the mother is married, whether it is the mother's first child, whether it is a singleton birth, whether the mother is a foreigner, the number of births, and net job creation by month and municipality and COVID incidence by province and month. Columns 3 and 7 also include the date of conception fixed effects (Date FE). Finally, columns 4 and 8 also include municipality fixed effects (Munic. FE).

[TABLE 2 HERE]

Looking at the models without the interaction term, it is shown that extreme temperatures negatively and significantly affect birth weight in the first and third trimesters of pregnancy. When a mother is exposed to extreme temperatures in the first trimester of pregnancy, newborn weight decreases by an average of about 16 grams when all control variables are included (column

Table 2: Effect of Energy Prices on Birth Weight for Mothers Suffering Extreme Temp. during Pregnancy

	Birth Weight							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	No int.	No int.	No int.	No int.	Int.	Int.	Int.	Int.
T1: ExtrT×After					47.588	45.448*	28.516	23.193
					(32.429)	(26.415)	(27.059)	(26.602)
T2: ExtrT×After					-26.593	-24.974	-6.846	-10.074
					(23.119)	(18.848)	(23.310)	(22.749)
T3: ExtrT×After					-3.164	-9.555	-30.719**	-32.859**
					(17.390)	(14.878)	(14.382)	(13.363)
T1: ExtrT	-10.477*	-7.990*	-10.560**	-15.508***	-10.643*	-8.145*	-10.687**	-15.599***
	(5.432)	(4.475)	(4.563)	(5.169)	(5.461)	(4.500)	(4.598)	(5.195)
T2: ExtrT	-10.435*	-7.377	-1.261	-4.874	-9.655*	-6.572	-0.964	-4.487
	(5.420)	(4.544)	(4.484)	(4.998)	(5.538)	(4.656)	(4.575)	(5.084)
T3: ExtrT	-58.234***	-47.133***	-52.372***	-55.118***	-57.988***	-46.437***	-50.102***	-52.703***
	(5.159)	(4.391)	(4.132)	(4.597)	(5.397)	(4.597)	(4.325)	(4.797)
Dem., Munic. & Prov.		✓	✓	✓		✓	✓	✓
Date FE			✓	✓			✓	✓
Munic. FE				✓				✓
N	1.41M	1.41M	1.41M	1.41M	1.41M	1.41M	1.41M	1.41M

Notes: Standard errors clustered by municipality and date of delivery are presented in parenthesis. All equations use as additional control variables: dummies by trimester of pregnancy, q that take value one when the mother is pregnant in the qth trimester of pregnancy. Dem., Munic. & Prov. include: the age of the mother and dummies indicating the gender of the newborn, if the mother is married, if it is the first child of the mother, if it was a singleton delivery, if the mother is foreign, number of births by month and municipality, net job creation and COVID incidence. Date FE: refers to date of conception fixed-effects. Munic FE: refers to municipality of residence of the mothers fixed-effects. * indicates significance at the 10% level, ** at the 5% and *** at the 1%.

4). When extreme temperatures occur in the third trimester of pregnancy, birth weight decreases by about 55 grams when all control variables are accounted for. Thus, it appears that the largest impact is found in the third trimester of pregnancy, which is consistent with what is found in the previous literature (Deschênes, Greenstone, and Guryan, 2009; Strand, Barnett, and Tong, 2012). The comparison of the results in the first four columns shows that the results are not significantly different in magnitude and significance, regardless of which set of controls is included.

In the regressions that include the interaction term between the increase in energy prices and exposure to extreme temperatures, it is shown that the effect of the interaction term is negative and significant for the third trimester of pregnancy once we date of conception fixed-effects. That is, the increase in energy prices for mothers exposed to extreme temperatures in the third trimester of pregnancy leads to a further decrease in newborn birth weight by an average of 30 grams once I include at least the second set of controls. Thus, when comparing the controls used, it appears that the inclusion of date of conception fixed-effects makes a large difference in the estimated results. However, the results do not differ significantly depending on which type of fixed effects is included.

Table 3 shows the results of the specification considered in the last column of the previous table, but analyzes the heterogeneous effects as a function of maternal vulnerability. That is, I estimate different regressions depending on whether a mother is married or unmarried and whether she is a foreigner or non-foreigner. In the first column, I include the baseline estimation of Equation 1 without accounting for heterogeneous effects to facilitate comparability of results, that is, the one in column 8 of previous table. In the second and third columns, I split the sample according to whether the mother is unmarried or married. As it is shown, the results of exposure to extreme temperatures are similar for unmarried and married mothers. However, the effect of the interaction of exposure to extreme temperatures with the increase in energy prices (in absolute terms) is larger when the mother is unmarried than when she is married. For unmarried mothers, an increase in energy prices associated with extreme temperatures in the third trimester of pregnancy leads to a 36 grams decrease in birth weight, whereas the estimated decrease for married mothers is about 29 grams. In the fifth and sixth columns, I split the sample according to whether the mother is a foreigner or a non-foreigner. In this case, the effect of exposure to extreme temperatures during the first and third trimesters of pregnancy is more negative for foreign mothers than for non-foreign mothers. Focusing on how the increase in energy prices affects mothers exposed to extreme temperatures during each trimester of pregnancy, I find that the effect is negative and significant for the third trimester of pregnancy, and that this effect is more negative for foreign mothers. Specifically, the increase in energy prices for mothers exposed to extreme temperatures during the third trimester of pregnancy translates into a reduction in birth weight of 48 grams on average for foreign mothers and 30 grams for native mothers. Thus, the increase in energy prices for mothers who suffered extreme temperatures during the third trimester of pregnancy had a more negative effect on newborn weight for the more vulnerable mothers (unmarried and foreign).

[TABLE 3 HERE]

Table 3: Effect of Energy Prices on Birth Weight for Mothers Suffering Extreme Temp. during Pregnancy: Heterogeneous Effects

	Birth Weight				
	(1) Baseline	(2) Unmarried Mother	(3) Married Mother	(4) Foreign Mother	(5) Non-foreign Mother
T1: ExtrT.×Aft	23.193	11.643	37.915	-4.618	29.722
	(26.602)	(29.813)	(32.256)	(40.633)	(28.863)
T2: ExtrT.×Aft	-10.074	-13.028	-5.792	-29.462	-7.015
	(22.749)	(23.293)	(24.435)	(29.206)	(23.609)
T3: ExtrT.×Aft	-32.859**	-36.274**	-29.485**	-48.168**	-30.355**
	(13.363)	(15.765)	(13.497)	(21.144)	(13.290)
T1: ExtrT	-15.599***	-14.917***	-16.122***	-18.982***	-14.916***
	(5.195)	(5.441)	(5.419)	(7.066)	(5.096)
T2: ExtrT	-4.487	-5.526	-3.700	-9.033	-3.622
	(5.084)	(5.383)	(5.261)	(7.242)	(4.922)
T3: ExtrT	-52.703***	-52.065***	-53.320***	-61.382***	-50.753***
	(4.797)	(5.163)	(5.020)	(6.786)	(4.732)
N	1.41M	679,000	734,000	271,000	1.14M

Notes: Standard errors clustered by municipality and date of delivery are presented in parenthesis. All equations use as additional control variables: dummies by trimester of pregnancy, q that take value one when the mother is pregnant in the qth trimester of pregnancy, the age of the mother, dummies indicating the gender of the newborn, if the mother is married, if it is the first child of the mother, if it was a singleton delivery, if the mother is foreign, number of births by month and municipality, net job creation and COVID incidence, municipality and date fixed-effects. * indicates significance at the 10% level, ** at the 5% and *** at the 1%.

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