Infant Anemia and the 2008 food price crisis in Senegal

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Abstract

I estimate the effects of the 2008 food price crisis on child hemoglobin in Senegal. Early-life hemoglobin reflects *in-utero* iron deposition, making it a bio-marker for maternal malnutrition. By comparing children *in-utero* during the 2008 crisis to those who were breastfeeding, I develop a quasi-experimental framework to quantify the impact of the 2008 crisis on maternal-infant health. I find large negative impacts of the crisis in urban Senegal, and no impact in rural areas. The effect was largest in Dakar, where it implied a more than doubling of the prevalence childhood anemia, from 1-in-3 children to 3-in-4.

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1 Introduction

In 2008, food prices around the world skyrocketed. On the international market, the price of rice tripled from January to April (FRED 2021).[1] In poor countries, where food expenditures often make up more than half of household expenditures (Seale Jr, Regmi, and Bernstein 2003), purchasing power collapsed as prices rose. The 2008 world food price crisis has drawn attention from the natural sciences (Moseley, Carney, and Becker 2010; Swinnen and Squicciarini 2012), economics (Benson, Mugarura, and Wanda 2008; D'Souza and Jolliffe 2014), demography (Alexandratos 2008; Naylor and Falcon 2010), food studies (McMichael 2009b; Kumar and Quisumbing 2013), nutrition (Brinkman et al. 2010; Martin-Prevel et al. 2012), peasant studies (Hossain and Kalita 2014; Bohstedt 2016), and development studies (Rosset 2008; Wodon and Zaman 2010). Recent food price spikes, such as those caused by the COVID-19 pandemic (Laborde et al. 2020) and the Russian invasion of Ukraine (Mottaleb, Kruseman, and Snapp 2022), has renewed interest in the 2008 crisis.

The 2008 crisis left no one unaffected, making it difficult to generate causal estimates of its effect on poverty and health. This lack of causal evidence has left a debate over the severity of the 2008 crisis for the world's poor. While some emphasize its negative impact on the urban poor (Moseley, Carney, and Becker 2010), others argue that the crisis raised income in rural areas, under the assumption that households in these areas typically sell excess foodstuffs(Aksoy and Isik-Dikmelik 2008).

I develop a novel quasi-experimental strategy, leveraging the biology of iron deposition during gestation and early childhood, allowing me to quantify the effects of the 2008 crisis on maternal-infant health in Senegal. I find that the 2008 crisis had a large effect on infant hemoglobin in urban Senegal, which likely reflects maternal iron depletion due to worsening diets. The effect of the 2008 crisis was large enough to cause a doubling of child anemia in Dakar, from 35% to over 70%. In Senegal as a whole, the effect implies a 30% increase in child anemia, from 47% to 64%, with the effects concentrated in urban areas.

Senegal is emblematic of today's challenges for population health and food security in West

[1] The exact causes of the crisis are unclear, but include financial speculation and export restrictions (Headey and Fan 2008).

Africa. It has a young, rapidly urbanizing population, without substantial economic growth or industrialization. As urbanization continues, Senegal's vulnerability to such crises as 2008 will only increase.

2 Background

2.1 Senegal

Senegal is located in the Sahel, on the west coast of Africa. With a GDP per-capita of less than $2,000 (current USD, World Bank data), Senegal is a low-income country, and is highly dependent on imported foodstuffs. Over the last 15 years, Senegal has seen limited economic growth, but substantial demographic expansion.[2] Roughly half of Senegal's population live in rural areas (World Bank), where subsistence agriculture is predominate (WFP). Senegalese society is marked by a high degree of mobility, including both internal migration (Delaunay et al. 2016 ; Herrera-Almanza and Sahn 2020) and emigration (Willekens, Zinn, and Leuchter 2017). Malnutrition is widespread in Senegal. Over half of women aged 15–49 suffer from anemia (DHS data), and over a fifth of children are stunted (Nene 2018).

Senegal imports 70% of its food supply (USDA Foreign Agricultural Service 2019), and the 2008 food price crisis led to widespread protests and unrest in Senegal and across West Africa (Le Monde 2008). This dependence on imported foodstuffs stems from French colonial and neo-colonial policy, with a characteristic pattern of trade – importing rice and exporting peanuts – established by the turn of the 20th century (Bonnefond and Couty 1988). Today, urbanization drives Senegal's continued increase in food imports.[3] In 1960, 1 in 5 Senegalese lived in cities. That number is 1 in 2 today (World Bank). This transformation has been accompanied by a "nutrition transition" (Popkin 1999), in which the population has shifted away from locally-produced coarse cereals (especially millet) towards imported foodstuffs, especially rice (CIRAD 2001) and wheat (Tikum 2022). This shift away from agriculture has

[2] According to the World Bank, Senegal's GDP per-capita has gone from $1420 in 2008 to $1598 in 2022. Total GDP has grown by 50%, driven largely by population growth.

[3] The specific pattern of urbanization in Senegal – largely concentrated in the '*presqu'ile du Cap-Vert*' which is Dakar – is also due to French colonial policies. For discussion, see, e.g., Wane (1985), Nelson (2007), and Harris (2011).

reduced Senegal's vulnerability to drought,[4] as fewer people depend on rain-fed agriculture for their livelihood. At the same time, this urbanization has increased Senegal's vulnerability to commodity-price volatility, as a growing number of people depend on international markets to meet their basic food needs.

The price of rice doubled in Dakar over the first half of 2008 (Figure 1). Most households in Senegal spend over half their budget on food (Figure 2). In a typical household, rice purchases alone make up about 20% of food expenditures (~10% of total expenses). Rice is a highly valued staple, whose importance has increased over time at the expense of more traditional crops like millet (CIRAD 2001). Rice consumption increases with income, but decreases as a share of food expenditures. Richer households diversify their diets into more expensive foods like meat and fish (CIRAD 2001). The 2008 price spike thus likely had the greatest effect on the urban poor, who lack both the financial security of richer urban households and the home-produced food of rural classes.

2.2 Literature

There has been more attention than consensus on the consequences of the 2008 food price crisis for the world's poor. Contemporary journalism focused overwhelmingly on the negative consequences of the 2008 price spike (e.g. Adam 2008; Bernard and Tuquoi 2008). Similarly, Moseley, Carney, and Becker (2010) take the negative impacts of the food price spike as given. They blame decades of "neoliberal policy reform" for reducing support for West African farmers, leading to further urbanization and dependence on imports. This perspective is shared by Rosset (2008), Mittal (2009), and McMichael (2009a, 2009b).

Food security surveys show a deterioration of diet quality over the course of 2008 in several countries around the world, with a shift away from nutrient-rich foods, but no change in quantity (overall calories) consumed.[5] Households protected their consumption of basic staples, like wheat and rice, by reducing consumption of expensive, nutritious foods like fish

[4]See Grace et al. (2021), for example, on the effect of local weather shocks on child health in neighboring Mali.

[5]See Hadley et al. (2011) and Kumar and Quisumbing (2013) for evidence from Ethiopia, Martin-Prevel et al. (2012) for Burkina Faso, D'souza and Joliffe (2012, 2014) for Afghanistan.

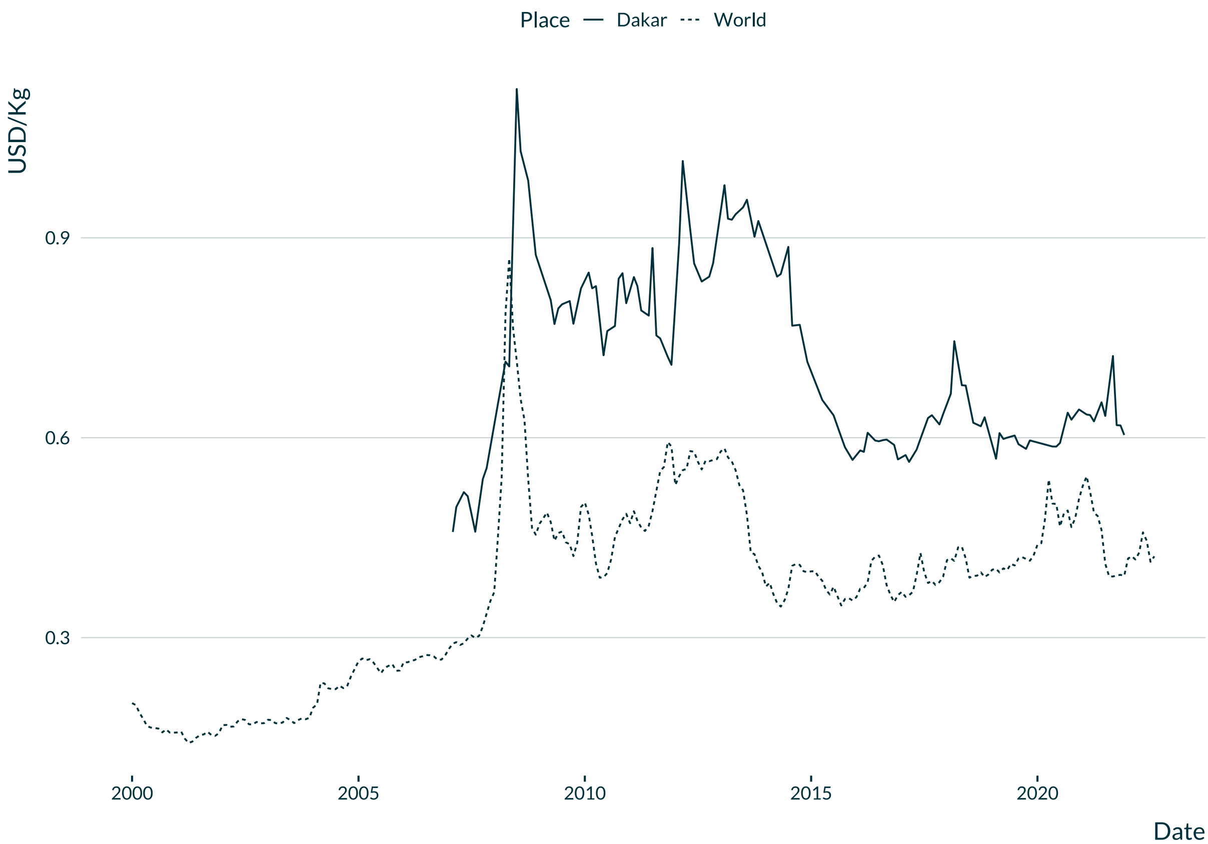

Figure 1: Price of Rice (USD/Kg) in Dakar and on the world market. Data from FRED and FAO.

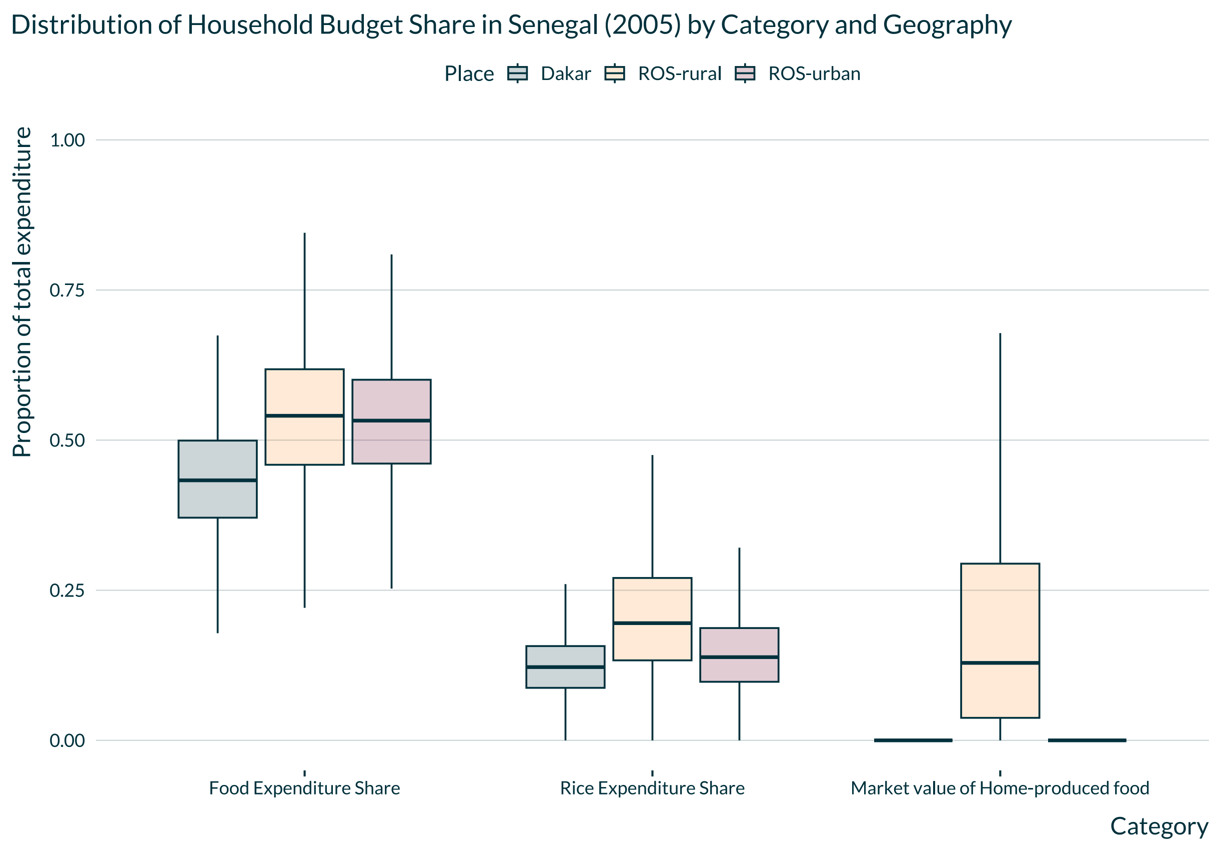

Figure 2: Budget shares from 2005 household survey data by geography, showing 25th and 75th percentile, along with the median, and whiskers of 1.5 times the interquartile range. Left panel is share of food in overall expenses; middle is the share of rice in food expenses; right is value of home-produced food relative to total food expenses. Data from the *Enquête de suivi de la pauvreté* (EPS) 2005.

and meat.

Child anthropometrics also show a negative effect of the 2008 crisis on child health. de Brauw (2011), Galab and Reddy (2013), Arndt et al. (2016), Lazzaroni and Wagner (2016), and Woldemichael, Kidane, and Shimeles (2017) all find that food price increases early in childhood were associated in increased wasting and/or stunting. However, it is difficult to draw causal claims from these studies, which are generally adjustment-based rather than quasi-experimental.

In contrast, results from household welfare analyses on the 2008 crisis are less clear.[6] Some authors highlight negative impacts of the 2008 price increase on household welfare (Ivanic and Martin 2008; Wodon and Zaman 2010; De Hoyos and Medvedev 2011; Ferreira et al. 2013; Balagtas et al. 2014; Hasan 2017). Others argue that the *net* effects of the 2008 crisis on poverty, once we account for gains to rural food producers, were relatively small (Mghenyi, Myers, and Jayne 2011; Dessus, Herrera, and De Hoyos 2008; Benson, Mugarura, and Wanda 2008). Furthermore, because rural food producers are on-average poorer than city-dwellers, the 2008 food price increase may have been 'progressive', raising rural income from sale of excess foodstuffs, and reducing the gap between rural and urban households (Aksoy and Isik-Dikmelik 2008; Dimova and Gbakou 2013; Minot and Dewina 2015; Van Campenhout, Pauw, and Minot 2018). Dimova and Gbakou (2013) queries whether the 2008 price increase was a "crisis" at all, or an "opportunity, or non-event"? This question has created a setting of "mixed messages" around food prices and poverty (Swinnen and Squicciarini 2012).

Welfare analysis based on budget data does not easily translate to health, as its methods assume the equivalence of incomes losses and gains, and ignore the intra-household allocation effects of price changes. In credit constrained households, an income loss will cause a larger negative effect on welfare than the positive welfare gain from an equivalent income gain. Therefore, a price shock could have negligible effects on aggregate real income, while still impacting public health and nutrition. Household welfare analysis also ignores the potential

[6]By 'household welfare analysis' I refer to the style of household budget analysis stemming from Deaton (1989).

effect of food price increases on intra-household power relations. If women are charged with buying food, for example, a food price shock could undermine their position within the household, and place them at risk of domestic violence (Ellis 1983; Gilbertson 2015).

Quantifying the health impacts of the 2008 crisis could resolve some of the debate over its impacts on the well-being for the world's poor. Because the 2008 crisis affected everyone in a given population, we cannot easily define a treated and control group, and existing empirical evidence is generally adjustment based. I contribute a novel quasi-experimental design to analyzing the 2008 food price crisis, leveraging the biology of iron deposition during pregnancy and early childhood.

2.3 Iron and Pregnancy

Iron is essential to the formation of hemoglobin, the oxygen-transport protein which facilitates aerobic respiration. Anemia is characterized by low levels of hemoglobin, and is most often due to iron deficiency (Kassebaum et al. 2014). For women, anemia causes fatigue and increases the probability of death during childbirth (Camaschella 2015). For infants, iron is a critical nutrient, and anemia can impair cognitive and motor development (Walter 2003).[7]

The amount of hemoglobin in blood is limited by iron availability, both for children and adults.[8] During pregnancy, the placenta transports iron to the fetus (Gambling, Lang, and McArdle 2011). The development of fetal hemoglobin is sensitive to maternal hemoglobin, with anemic mothers giving birth to anemic infants (Akhter et al. 2010). There is little iron in breast milk (Domellöf 2007), and the breastfed infant relies on stores of iron accumulated during gestation (Friel, Qasem, and Cai 2018). The amount of iron in breast milk is insensitive to maternal hemoglobin (Loh and Sinnathuray 1971), except in cases of severe anemia (Kumar et al. 2008).

A change in maternal diet, and therefore iron availability, should therefore have an effect

[7] Maternal and infant hemoglobin has been used as outcomes in a wide range of social science research. See, for example, Block et al. (2004), Kumar, Molitor, and Vollmer (2016), Sunder (2019), Von der Goltz and Barnwal (2019), or Yue et al. (2020).

[8] Lack of available iron can come from depletion of iron stores, but also from increased iron sequestration due to inflammation (Camaschella 2015). In this paper I focus on the former.

on iron stores of infants *in-utero* during this change, but not those who were breastfeeding. As breastfeeding is quasi-universal in Senegal (Boye 2016), the cohorts born just before the 2008 crisis should be, in terms of iron, insulated from its effects. The cohorts *in-utero* during and after the crisis should have been affected, as depletion of maternal iron stores would result in less iron being transported to the fetus. This difference offers a quasi-experimental framework for evaluating the effect of the 2008 crisis on maternal nutrition.

3 Data and Methods

I use data from the Demographic and Health Survey (DHS) in Senegal, which gives repeated cross-sections of children under the age of five, and women aged 15–49. These data run from 2005 to 2020, and include child, woman, and household characteristics. I also draw on household living standards surveys from the Senegalese government.

After dropping observations without hemoglobin measures, I have a sample of just over 40,000 children. Nearly 3250 of these are from the 2010 survey, meaning the children were born sometime from 2006–2010. Just under 1300 observations belong to my treatment and control groups: i.e., were either breastfeeding during the crisis (born July 2007 to April 2008) or *in-utero* during the crisis (born between June 2008 and April 2009).

The hemoglobin of infants *in-utero* during the crisis should have been sensitive to changes in maternal nutrition, unlike those who were breastfeeding. I take the *in-utero* cohort as my treated group, and those who were breastfeeding as the control.

The remainder of the sample are included in order to calibrate the effect of relevant covariates, such as household wealth and mother's age and education. My control and treatment groups are roughly balanced across these observable characteristics (except for a slight difference in maternal age, see Table 1), but differ in terms of child age. Hemoglobin follows a definite age-path (see Figure 10), decreasing over the first year of life, and increasing thereafter. I therefore adjust for age in all regressions. I include other relevant covariates in order to improve the precision of my estimates.

I define "Treated" as *in-utero* during the crisis (born between June 2008 and April 2009);

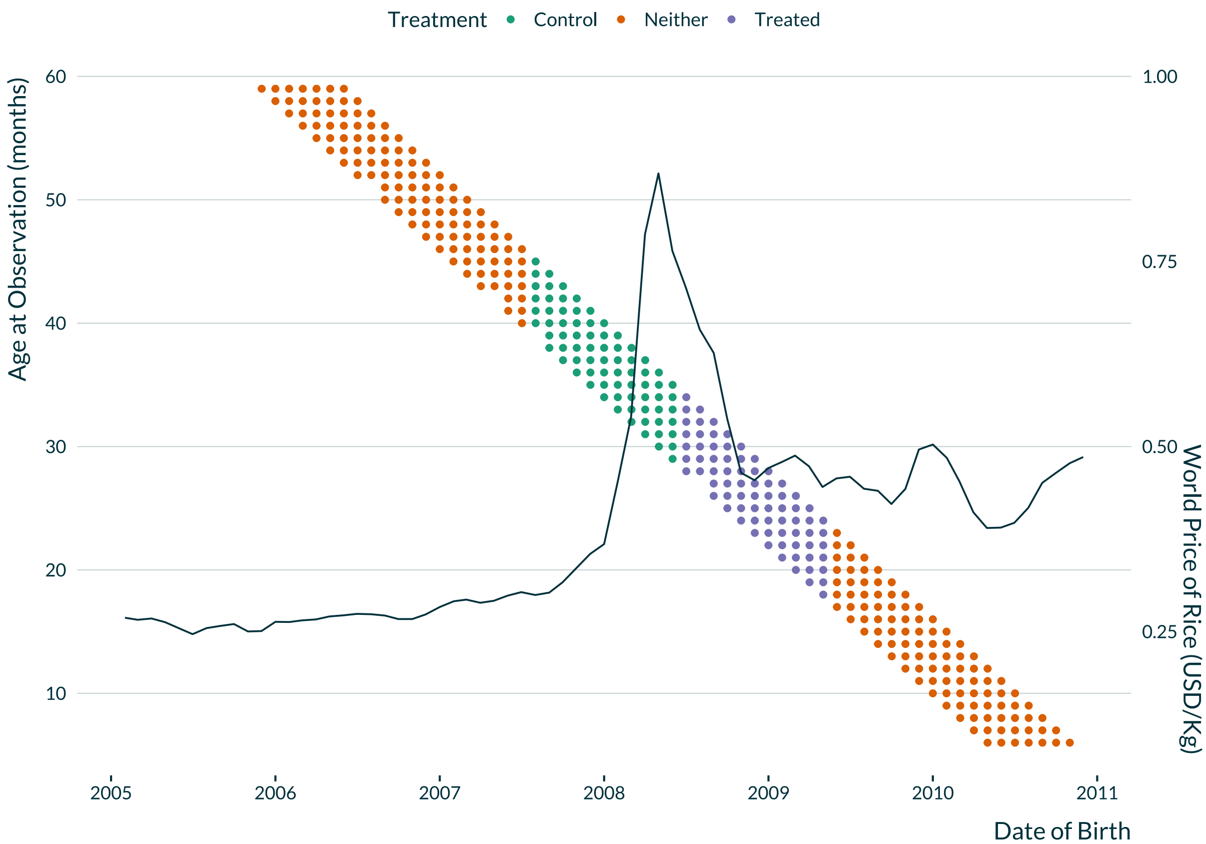

Figure 3: Treatment definition of birth cohorts, plotted by age at observation against date of birth. Data from the 2010 Senegal DHS. The world price of rice plotted against the right-side axis for reference.

Table 1: Balance of Treatment

	Mother's Age	Mother's Education	Urban	Wealth
Treated	-0.78	0.12	-0.02	-0.09
	(0.37)	(0.13)	(0.12)	(0.06)
N	1301	1301	1301	1301

"Control" as breastfeeding during the crisis (born July 2007 to April 2008); and "Neither" as all other cohorts. I interact treatment status with geography (Dakar, rest of urban Senegal, and rest of rural Senegal).

$$(1) \quad hemo = \beta_1 + \beta_{2,j} Treated + \beta_{3,j} Neither + g(age) + X + \epsilon$$

where $\beta_{2,j}$ are the coefficients of interest, where j denotes geography . $hemo_i$ is infant hemoglobin, $g(age)$ is a cubic spline of age in months, and X is a vector of covariates.

For an alternative specification, based on a data-driven measure of *in-utero* price shock exposure, see the appendix.

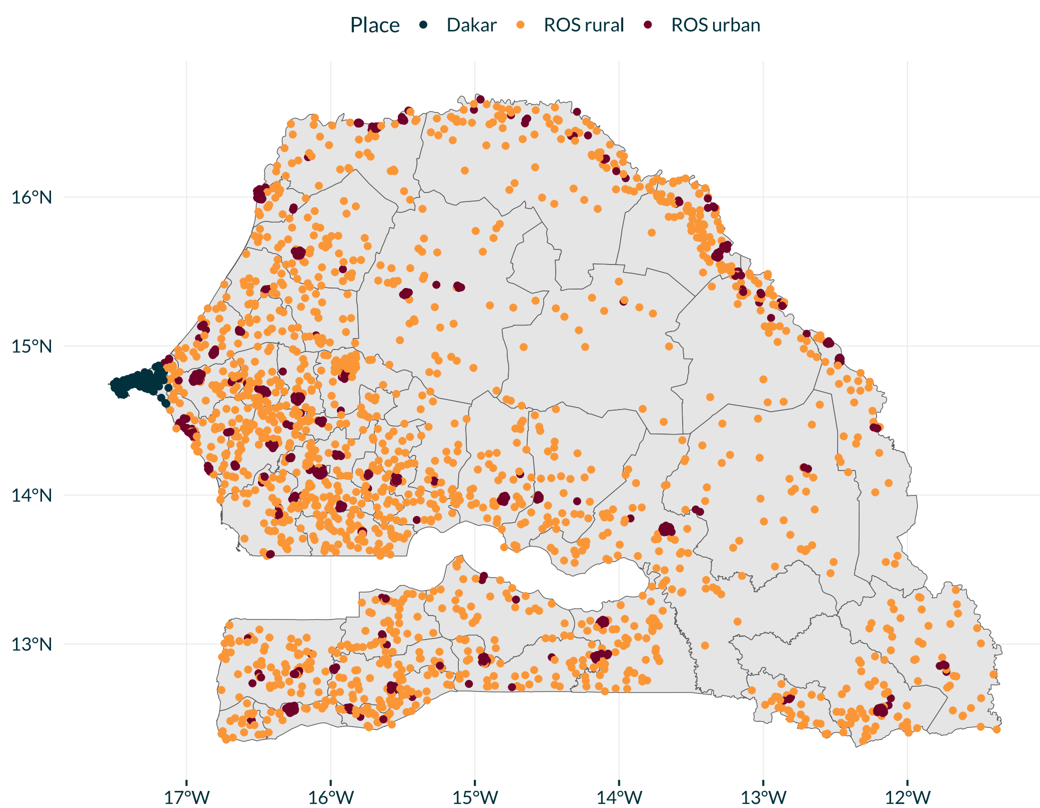

Figure 4: Map of Senegal DHS data. Map boundaries are *départements*. Points are DHS clusters 2005–2020, colored by geography relevant to my regressions. Map from *gadm.org*.

4 Results

I present median hemoglobin by birth cohort, split by geography (Dakar or rest of Senegal). June 2008, when rice prices spiked in Dakar, is given by a dashed vertical line. Another dashed line is given by October 2007. The cohorts born between the dashed lines were breastfeeding during the crisis. The onset of the crisis coincides with a sharp decline in hemoglobin in the Dakar population. The points are colored by *in-utero* price exposure (described above). We see that the deterioration of child hemoglobin in Dakar is strongest in the cohorts with the greatest *in-utero* exposure to the 2008 rice price increases. The cohorts with the highest levels of hemoglobin are those who were breastfeeding during the crisis. The deterioration in the rest of Senegal is much smaller than in Dakar.

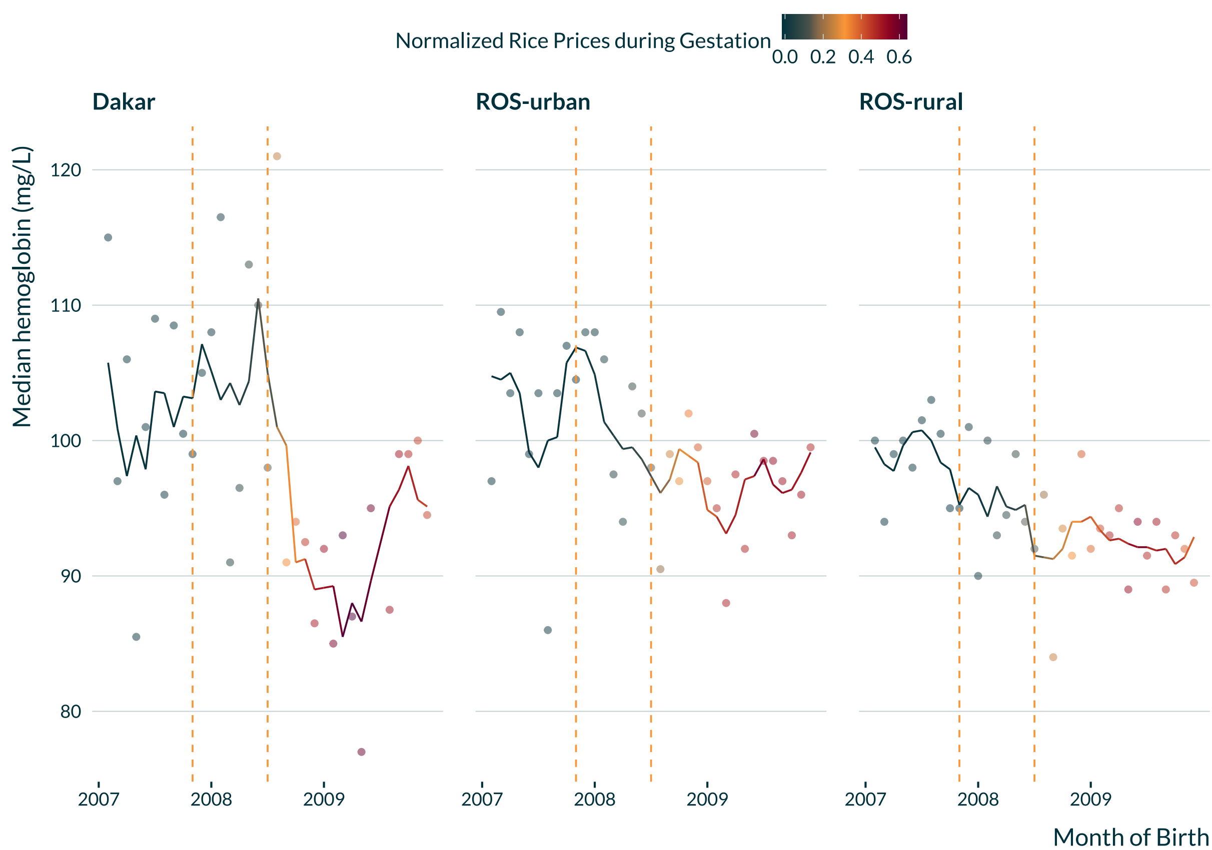

Figure 5: Median hemoglobin in Senegal 2010 by birth-month cohort, divided by geography. Points are the values, and the lines are the rolling mean, centered with a window of 4 months. Control cohorts (breastfeeding during crisis) are between the dashed lines; Treated cohorts (*in-utero* during crisis) are to the right of the second dashed line. Color represents normalized rice prices during gestation. Data from the DHS and FAO.

The data suggest that the 2008 crisis had a substantial effect on infant hemoglobin in Dakar. In order to quantify this effect, I estimate equation (1), allowing for the treatment effect to vary for three subsets of Senegal: Dakar, rest of Senegal (ROS) urban, and ROS rural. The estimated level of hemoglobin across treatment status and effects are plotted in Figure 6. The 2008 crisis was associated with a large deterioration in child hemoglobin in Dakar, a smaller one in the rest of urban Senegal, and no effect in rural Senegal.

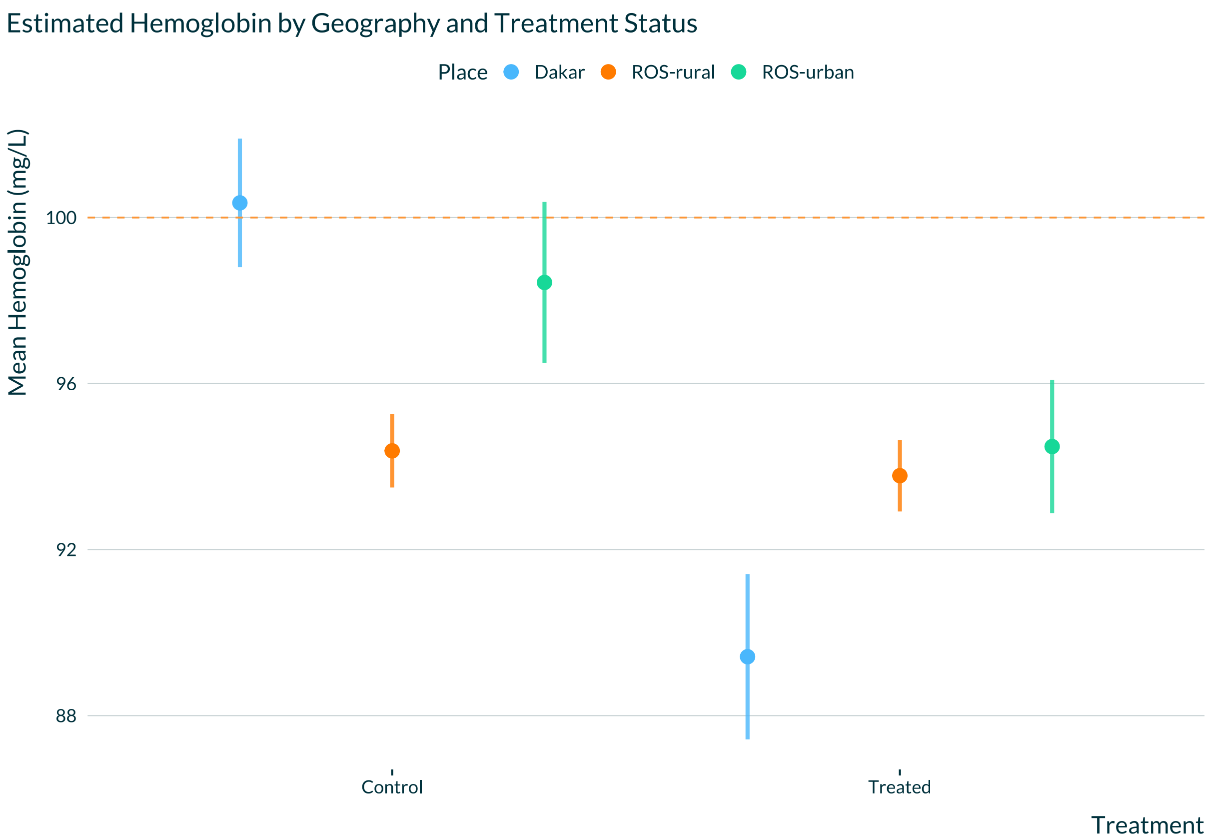

Figure 6: Effect of the 2008 Food Price Crisis on childhood hemoglobin in 2010, estimated by equation (1). Children breastfeeding during the crisis are the control, and who were *in-utero* are treated. Treatment effect allowed to vary by geography (Dakar, ROS-urban, ROS-rural). Lines are (robust) standard errors. The horizontal line at 100 mg/L is a cutoff for moderate-to-severe anemia. Data from the DHS.

4.1 Quantile Regression and Implications for Anemia

In order to quantify the effect of the 2008 crisis on anemia, I use quantile regression. I estimate equation (1) for Senegal as a whole, and then separately for Dakar, ROS-urban, and ROS-rural. I remove all controls except for child age, in order to make inferences of the effect of the 2008 crisis on anemia in the broader population.[9] I estimate the regression at each ventile.

The results follow the same patterns as above, with the effect of the 2008 crisis largest in Dakar, followed by urban Senegal, and with no clear effect in rural areas. The effect at the extremes of the distribution are smaller than in the center (Figure 7), likely because of attrition at the left tail (mortality) and the the ability to consumption smooth at the right tail (as high-hemoglobin children are likely to come from food-secure families).

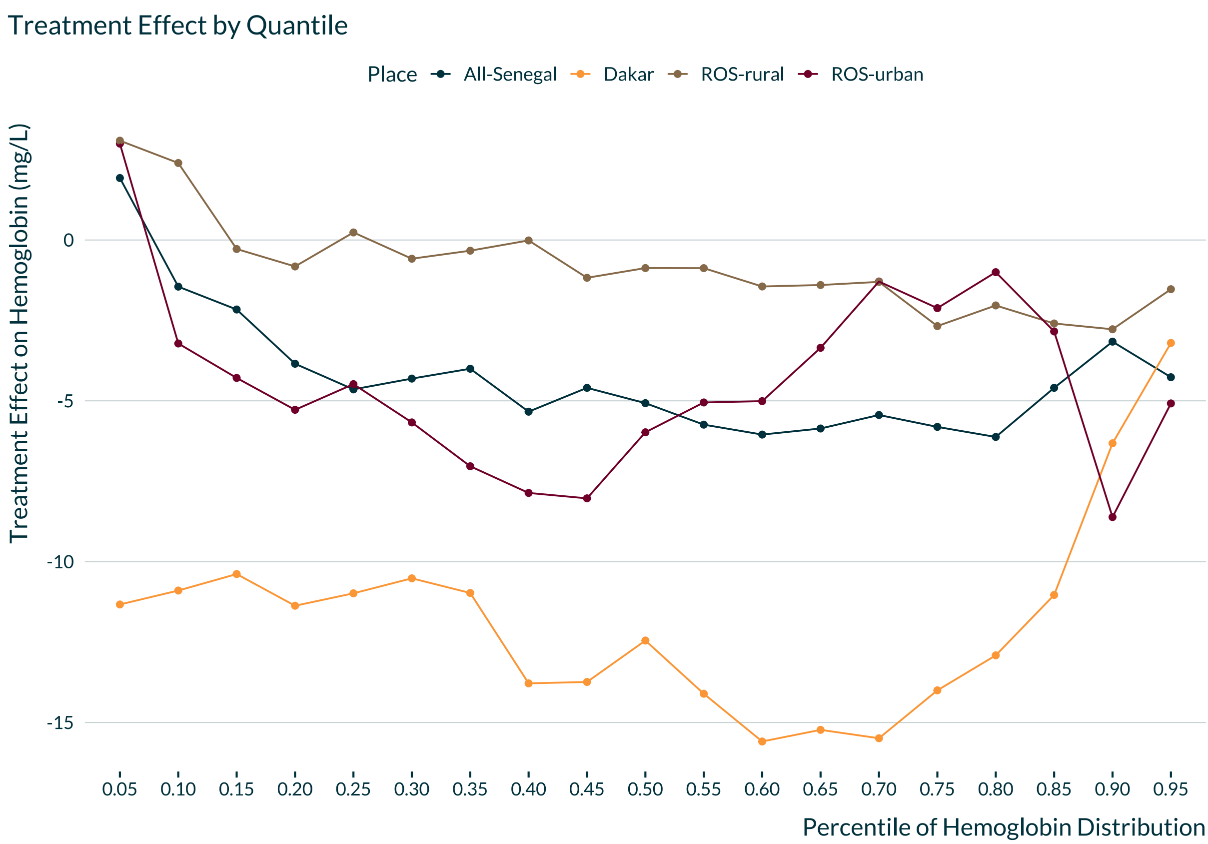

Figure 7: Quantile regression results, by geography. Effect of exposure to the 2008 crisis by quantile. Conditioned on child age. Data from the DHS.

I then take the rest of my sample (years 2005 and 2012–2020), and sort observations into percentiles. For each observation I apply the estimated treatment effect from the corresponding

[9]I am interested in the treatment effect on the unconditional distribution, rather than the conditional distribution. See Killewald and Bearak (2014) for discussion of conditional vs. unconditional quantile effects.

quantile regression. I.e. an observation in the 20th percentile of the anemia distribution in Dakar would be given the treatment effect of the 20th percentile of the Dakar regression (the second point from the right in the Dakar line in Figure 7).

Applying the effect of the 2008 crisis to the rest of my sample (years 2005 and 2012–2020) implies a 30% increase in child anemia in Senegal across these years: from 47% to 63%.[10] For Dakar, my estimates imply and increase in child anemia from 33% to 76%. Repeating this exercise in the rest of urban Senegal, I find a 1/3 increase in anemia, from 40% to 56%. In rural Senegal, the effect is small, with anemia increasing from 51% to 54%.

5 Discussion and Conclusions

The 2008 crisis had a large effect on infant hemoglobin in urban Senegal. This effect was strongest in Dakar, where it implied 10% decline in mean hemoglobin. Based on quantile regression results, this translates into more than a doubling of the prevalence of anemia, from about 1-in-3 children to 3-in-4. The effect was smaller in the rest of urban Senegal, and close to null in rural areas.

The affected children were *in-utero* at the time of the crisis, suggesting that maternal iron depletion was responsible for their low hemoglobin. I cannot directly test for maternal iron depletion, as there is no continuous data on women's hemoglobin in Senegal over the period, but I compare hemoglobin levels in 2005 to those in 2008 and 2010.

Figure 8 plots median hemoglobin of women in Senegal for 2005, 2008 and 2010, ages 15–45. In 2005 women's hemoglobin was highest in Dakar, followed by other cities in Senegal, and lowest in rural areas. Between 2005 to 2008, women's hemoglobin deteriorated in urban Senegal, particularly in Dakar, while improving slightly in rural areas. This pattern supports the proposed mechanisms of maternal iron depletion leading to reduced iron accumulation *in-utero* for affected cohorts, and therefore lower iron stores in early childhood.

Existing studies find diet-quality deterioration during the 2008 crisis (Hadley et al. 2011; Martin-Prevel et al. 2012; Kumar and Quisumbing 2013; D'Souza and Jolliffe 2012, 2014).

[10] I use 100 mg/L of hemoglobin as a cutoff for moderate-to-severe anemia, as in Wang et al. (2015).

Figure 8: Mean hemoglobin among women in Senegal, by geography. Data from the DHS.

These authors emphasize that households cut back on expensive, nutritious ingredients (e.g. fish and meat) while maintaining cereal consumption. Such a change would cause iron depletion by reducing the heme iron in the diet. Leport (2017) notes a similar pattern over a longer period, where households in Dakar respond to the increasing scarcity of fish by reducing its quantity in rice-based dishes.

My results suggest that such changes in diets had dire consequences for maternal-infant health. The first 1000 days are a crucial phase in human development, and iron in particular is a critical nutrient in child development (Lozoff et al. 1998; Walter 2003). The effects of the 2008 crisis are likely still felt today by those whose mothers were affected, contributing to the 'reproduction' of social inequalities (Palloni 2006). Similar effects are likely being felt around the world due to recent food price crises.

I find no evidence of any positive effects of the crisis on maternal-infant health in rural areas, unlike the predictions of existing work on household welfare (Dessus, Herrera, and De Hoyos 2008; Benson, Mugarura, and Wanda 2008; Aksoy and Isik-Dikmelik 2008; Mghenyi, Myers, and Jayne 2011; Dimova and Gbakou 2013; Minot and Dewina 2015; Van Campenhout, Pauw, and Minot 2018). The malnutrition caused by the 2008 crisis in urban Senegal was not offset by any improvements in rural areas.

Higher rice prices did not help the rural population of Senegal. This is likely because the vast majority of them do not sell staple goods, although they do produce them. According a 2010 household living standard survey conducted by the Senegalese government (EPS 2010), 20% of agricultural households in Senegal produce some rice. Only 30% of these households sell rice.[11] Sale of staple goods is not a part of most household livelihoods in Senegal. But nearly all agricultural households in Senegal (93%) purchase rice. Although most rural households in Senegal practice agriculture, staple crops are mainly for subsistence, not sale, likely reflecting the moral economy of staple goods[12]

That being said, I find no evidence of negative effects of the food crisis on rural households.

[11]Similarly, 70% of agricultural households in Senegal produce millet. Only 1/4 of these sell millet.

[12]Informally, I was told in the Casamance region of Senegal, famed for its rice production, that households do not sell their rice. Rice is kept for the family. Rice might be gifted, particularly to extended family members in urban areas, or to local families who are struggling to make ends meet, but is generally not sold.

This is likely because rural households in Senegal have some control over the means of food production – arable land – giving them relative autonomy. Urban classes, on the other hand, depend on market relations to meet their basic food needs, making them particularly sensitive to shifts in exchange relations, such as food price spikes.[13]

The ongoing class transformation in Senegal, with a growing proportion of urban laborers, will only increase vulnerability to crises like 2008. The same transformation is occurring across much of sub-Saharan Africa, driven by structural economic change (CIRAD 2017), demographic expansion (Fox 2012) and urban population growth (Parnell and Walawege 2011). Senegal, in being more urbanized than neighboring countries, is not an exception but a portend.

Senegal's vulnerability to world food price volatility is well known by the local population, both in the streets and in government. After the 2008 crisis, the national government (under current President Macky Sall) made massive investments in rice production in the Senegal River Valley, hoping to reduce their staple import dependency (Demont and Rizzotto 2012).

While these investments have increased rice production, they have failed to reduce imports. Moreover, over the last 20 years Senegal has developed a similarly large dependency on imported wheat (FAO 2020). These joint import dependencies leave the Senegalese food system arguably even more vulnerable to international economic and geopolitical volatility today than it was in 2008.

Sen (1982: 173) observed half a century ago that "The phase of economic development after the emergence of a large class of wage laborers but before the development of social security arrangements is potentially a deeply vulnerable one." In Senegal, this set of class relations, with a large urban class of wage workers with limited social protections, does not seem like a 'phase'. It is the new normal, as are the set of challenges to food security and population health which come along with it. These include world food price volatility, but also climate change, which will undermine existing livelihoods across the Sahel (Sissoko et al. 2011). Senegal is responsible for neither, but faces the consequences of both.

[13]Sen (1982: 6) highlights this distinction in his classic treatment of class and food security.

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7 Appendix

7.1 Regression Tables

Table 2: Least-Squares Regression results for equation 1 (columns 1) and equation 2 (column 2). All regressions adjusted for mother's age and education, child age, and household wealth.

	Binary Treatment	Price-Exposure
Treated	-8.63	
	(2.03)	
Wealth	2.52	2.54
	(0.11)	(0.11)
ROS-urban:Treated	4.10	
	(2.60)	
ROS-rural:Treated	4.50	
	(2.21)	
Price		-15.71
		(3.25)
ROS-urban:Price		7.24
		(5.42)
ROS-rural:Price		16.16
		(3.96)
N	43025	43025
R2	0.11	0.11

Standard errors are heteroskedasticity robust. .

7.2 Local Rice Prices in Senegal

Here I plot the local price of rice from 10 markets in Senegal, corresponding to 10 of the 11 regions of Senegal in 2007. I take 2007 as a reference period, and then plot the relative price increase $(log(\frac{p_{it}}{\bar{p}_i}))$ in each market.

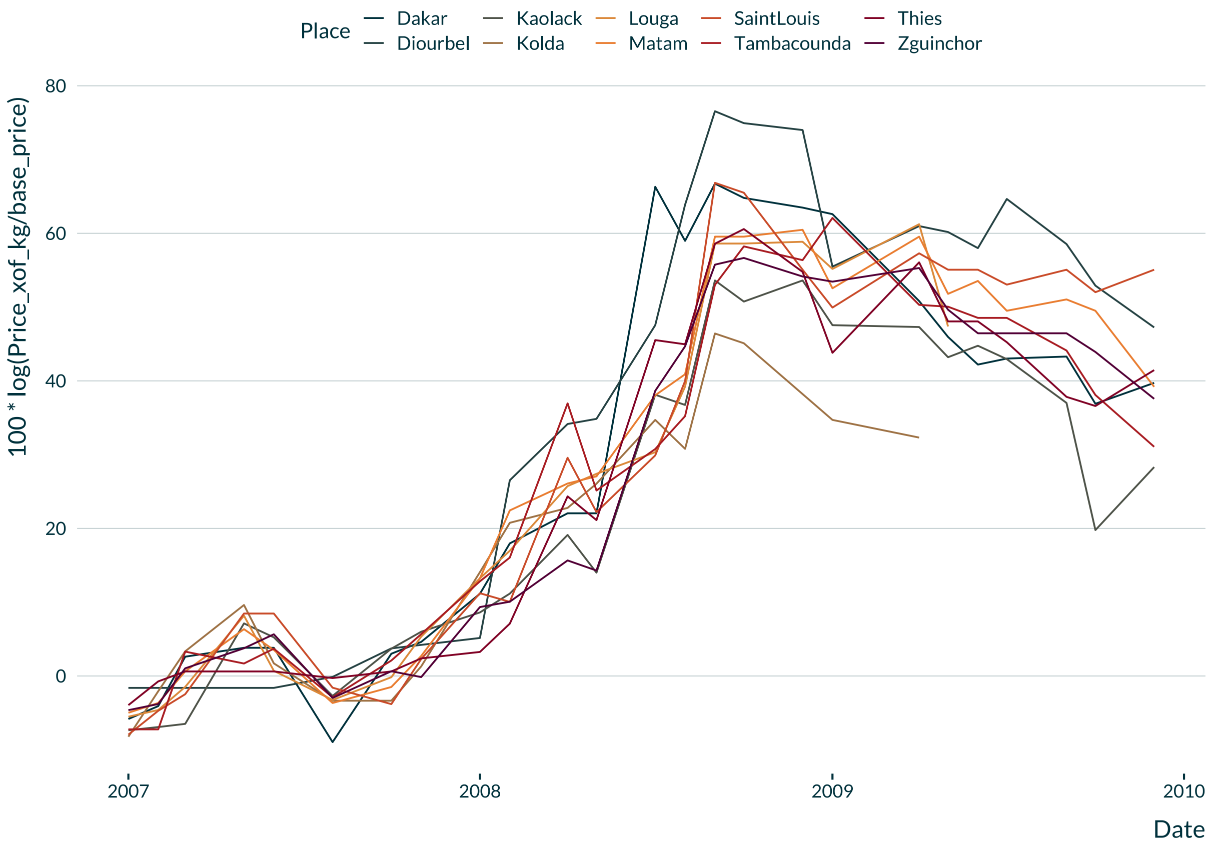

Figure 9: Retail rice prices in Senegal, relative to 2007 average. Data from the FAO FPMA tool, accessed September 19, 2022.

7.3 Hemoglobin by Age

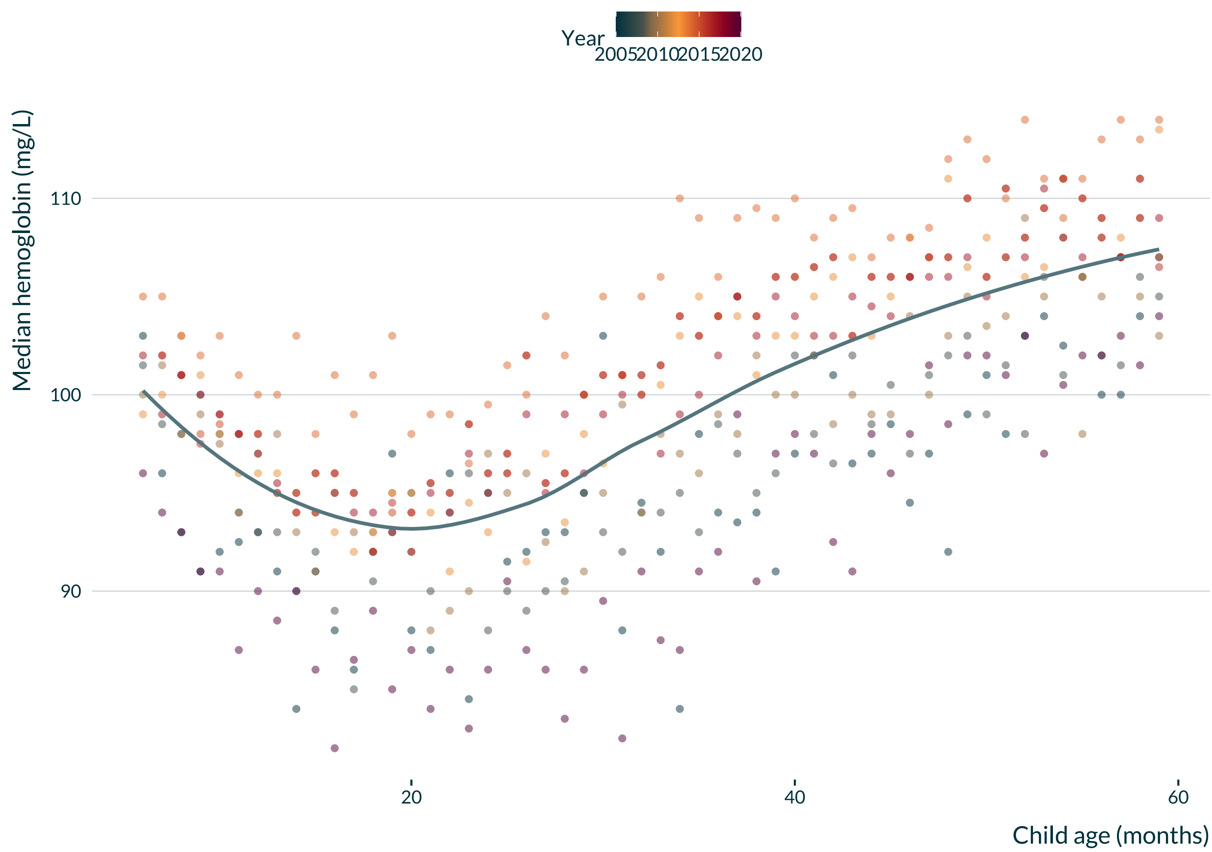

Figure 10: Median hemoglobin by child age and year of survey, Senegal DHS data 2005-2020.

7.4 Alternative regression specification

I create a data-driven measure of *in-utero* exposure to the price shock. I take retail rice price data from 10 regional markets in Senegal (see Figure 9 for plots of these data, and calculate a pre-2008 average ($\bar{p}_i$). I take the rice price relative to the pre-2008 standard: $\Delta p_{t,i} = log(\frac{p_{t,i}}{\bar{p}_i})$ for each market i and month t. For each cohort-market, *in-utero* price exposure is the average of this normalized rice price during the nine months prior to birth, denoted by $\Delta_i = mean_t(\Delta p_{t,i})$. I estimate the following equation:

$$(2) \quad hemo = \alpha_1 + \alpha_{2,j}\Delta + \alpha_{3,j}Neither_{+}\alpha_{4,j}(\Delta|Neither) + g(age) + X + \epsilon$$

The coefficients of interest are the effects of price exposure on those in either the "Treated" or "Control" groups ($\alpha_{2,j}$), which vary by geography j (Dakar, rest of urban Senegal, rest of rural Senegal).

Next I estimate equation (2), allowing for an intensive margin of treatment and for the timing of treatment to differ across regions. A 2-σ increase in price exposure *in-utero* results in a nearly 16 mg/L decrease in hemoglobin in Dakar and a 9 mg/L decrease in the rest of urban Senegal. The effect in rural Senegal is close to null. These results are consistent across the two specifications.

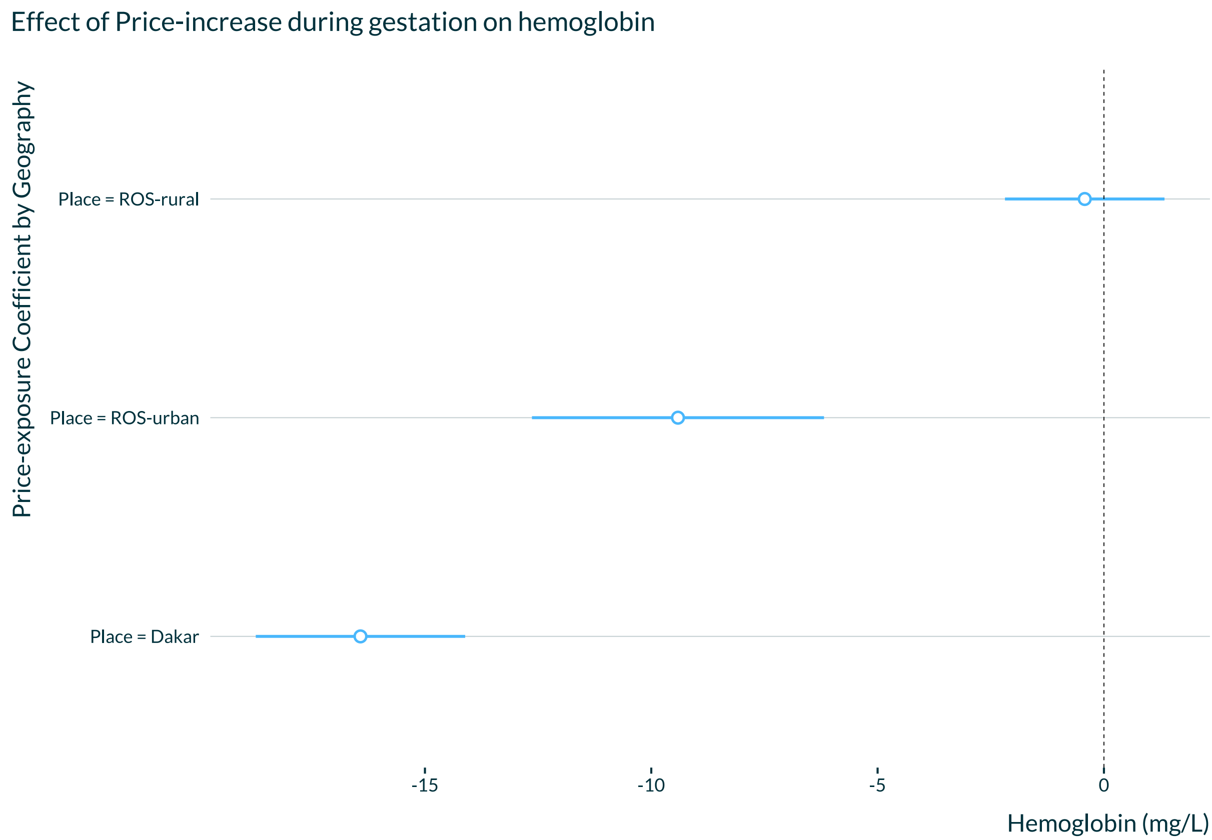

Figure 11: Effect of the 2008 Food Price Crisis on childhood hemoglobin in 2010. Treatment is measured by normalized rice prices in the closest regional market at the time of gestation. The coefficient compares children breastfeeding during the crisis to those who were *in-utero*. Coefficient on price exposure allowed to vary by geography (Dakar, ROS-urban, ROS-rural). Lines are (robust) standard errors. Data from the DHS.

8 Data sources

Demographic and Health Surveys

Enquête de suivi de la pauvreté au Sénégal (2005)

Enquête de suivi de la pauvreté au Sénégal (2010-2011)

FAO FPMA Tool

World Bank Open Data

FRED Economic Data

9 Software used

Analysis done in R version 4.3.1 (2023-06-16), with the following packages:

Table 3: R Packages

Package	Loaded version	Date	Source
data.table	1.14.8	2023-02-17	CRAN (R 4.3.0)
dplyr	1.1.2	2023-04-20	CRAN (R 4.3.0)
forcats	1.0.0	2023-01-29	CRAN (R 4.3.0)
ggplot2	3.4.2	2023-04-03	CRAN (R 4.3.0)
huxtable	5.5.2	2022-12-16	CRAN (R 4.3.0)
interactions	1.1.5	2021-07-02	CRAN (R 4.3.0)
jtools	2.2.1	2022-12-02	CRAN (R 4.3.0)
kableExtra	1.3.4	2021-02-20	CRAN (R 4.3.0)
knitr	1.42	2023-01-25	CRAN (R 4.3.0)
lubridate	1.9.2	2023-02-10	CRAN (R 4.3.0)
mediocrethemes	0.1.3	2023-05-10	Github (vincentbagilet)
purrr	1.0.1	2023-01-10	CRAN (R 4.3.0)
quantreg	5.95	2023-04-08	CRAN (R 4.3.0)
readr	2.1.4	2023-02-10	CRAN (R 4.3.0)
SparseM	1.81	2021-02-18	CRAN (R 4.3.0)
stringr	1.5.0	2022-12-02	CRAN (R 4.3.0)
tibble	3.2.1	2023-03-20	CRAN (R 4.3.0)
tidyr	1.3.0	2023-01-24	CRAN (R 4.3.0)
tidyverse	2.0.0	2023-02-22	CRAN (R 4.3.0)