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Evidence from Ecuador

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Abstract: A micronutrient deficiency during infancy impairs growth, increases the risk of mortality, and can have long term effects on cognitive development. We evaluate a nationwide public policy that administered "sprinkles" to reduce iron-deficiency anemia in children 6 to 59 months of age in Ecuador, a country that has persistent problems with iron-deficiencies among children. We exploit the exogenous age eligibility rule of the program to identify its causal effect, and address non-compliance issues with a Fuzzy RD design and IV models. Our IV estimates suggest that the program reduces Hb levels in children with low Hb but increases Hb levels in children with higher Hb levels. On average, these heterogeneous effects cancel out and both RD and IV estimates yield insignificant effects.

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1. Introduction

Micronutrients, particularly iron, zinc and vitamin A, folic acid and iodine, play a vital role in childhood development. A micronutrient deficiency during infancy affects growth, the immune system, may increase the risk of mortality, and can have long term effects on cognitive development and schooling achievements (Martinez, et al., 2009). Iron-deficiency anemia (IDA) is a condition characterized by a depletion in iron reserves leading to a lower than normal level of Hb in the blood (U.S. Department of Health and Human Services, 2014).[1] It is the most widespread micronutrient deficiency in the world (WHO, 2015), approximately 40% of the infants in developing countries are iron deficient (Micronutrient Initiative, 2015), and it is the only nutrient deficiency which is also significantly prevalent in industrialized countries (WHO, 2015).

This paper evaluates the current Ecuadorian national public policy to reduce IDA in children 6 to 59 months of age. Ecuador is an important case study for the evaluation of public policy to reduce IDA as it has had a persistent problem with iron-deficiencies among children. In 1986 a diagnostic study on the nutritional health of children found that 69% of 6 to 12 month olds had anemia (Freire, et al., 1988). In 2012 the national Health and Nutrition Survey (HNS[2]) shows that the incidence in the same age group is 62% indicating a 7% reduction in 26 years. (Ministerio de Salud Publica; Instituto National de Estadisticas y Censos, 2013).

The national nutritional program relies on supplements developed to prevent and treat micronutrient deficiencies among young children.[3] The program distributes nutritional supplements to the parents of children attending public daycare and public healthcare centers nationwide. The policy rule stipulates that children under the age of 59 months (5 years old) are eligible to receive the treatment, therefore, children over this age are no longer eligible (Ministerio de Inclusion Economica y Social, 2012; Ministerio de Inclusion Economica y Social, 2013).

The 2012 HNS[4] is a cross-section survey which covers participation in public nutritional supplement programs and includes a sub-sample of 2047[5] children 6 to 59 months old who had blood samples taken

[1] Hb is an iron-rich protein that carries oxygen from the lungs to the rest of the body.
[2] The National Health and Nutrition Survey (ENSANUT, which we refer to as HNS) is a cross-section database built by the National Institute for Statistics and Censes (INEC) in Ecuador between 2011 and 2013.
[3] "Sprinkles" were developed to prevent and treat micronutrient deficiencies among young children (Ministerio de Salud Publica, World Food Program, 2011).
[4] The National Health and Nutrition Survey (ENSANUT, which I refer to as HNS) is a cross-section database built by the National Institute for Statistics and Censes (INEC) in Ecuador between 2011 and 2013.
[5] Out of a total sample of 11506 children under the age of 5.

and Hb measured.[6] To identify the causal effect of the policy we apply two methods: Regression Discontinuity (RD) and Instrumental Variables (IV).

The RD model uses the age eligibility to randomly divide the children around the cut-off into treatment and control groups. Those who are just under the age cut-off are in the treatment group and those who are just over the age cut-off are in the control group. The aim of the exercise is to define a sufficiently small bandwidth around this cut-off such that the control group is an appropriate counterfactual, in its (un)observable characteristics, to the treatment group. We explore various bandwidths and functional forms to examine the robustness of our results.

In the IV model, we use the same cut-off as an exogenous instrument to treatment. This is an exogenous instrument because children cannot manipulate their age in order to receive the treatment. Additionally, using the IV model we present heterogeneous effects for three Hb levels.

The HNS does not provide information on treatment completion. This may be important given the treatment requires at least 60 doses (once a day) to be taken at most over the span of 4 months (Ministerio de Coordinacion de Desarrollo Social, 2011). Therefore, interrupting the treatment may have a deterministic effect on the outcome. In randomized trials, the issue of non-compliance is accounted for with an "intention to treat" (ITT) model where the effect of the treatment is estimated regardless of whether the patients completed the treatment or not (Armijo-Olivo, et al., 2009). The ITT model gives an estimate of the effect of a change in treatment policy rather than an estimate of the effect of the treatment in patients who comply with it (Hollis & Campbell, 1999). The models applied in this study (RD and IV) identify the unbiased effect of the program by using the eligibility rule as an instrument.

We find no significant effect of the change in the treatment policy (or the intention to treat) in any of the RD models, and, nor in the IV model with no heterogeneous effects. When heterogeneous effects by Hb levels are included, we find a negative significant effect for children with low Hb and a positive significant effect for children with higher Hb levels. This suggests that these two opposing effects cancel each other out when measuring the average effect. The negative effect may be due to possible non-compliance with the number of required doses. Additionally, the supplement can cause constipation or diarrhea, particularly among younger children who have never had "sprinkles" before (Ministerio de Salud Publica, World Food

[6] Among other biomarkers

Program, 2011). Therefore, the effect of the treatment might reduce Hb if the children get diarrhea and/or stop receiving doses.

Our study is an important contribution to the literature on the nutritional health of children, as we believe it is the first paper that examines the causal impact of a nationwide nutritional program on Hb in Latin America.

The rest of the paper is structured as follows. We next provide a description of the Ecuadorian context and a revision of the literature on supplementation and transfer programs in developing countries. Section 3 explains the program, describes the data available, discusses our main empirical challenges and our empirical strategy. Section 4 presents our main findings, while the last section concludes.

2. Context and review of the literature

Ecuador is a small upper middle-income country (The World Bank, 2016) in Latin American which has seen important social improvements in the past decade. The incidence of poverty has gone down from 37% in 2007 to 23% in 2015; the incidence of extreme poverty has gone from 16% to 8% and the Gini coefficient from 0.55 to 0.47 in the same period (Instituto Nacional de Estadistica y Censos, 2015). Notwithstanding, Ecuador can be described as a country with pronounced social, regional and ethnic disparities with high levels of poverty and inequality (Larrea & Kawachi, 2005; Farrow, et al., 2005).

IDA refers to a condition in which a deficiency in iron leads to a lower than normal number of red blood cells and those which are produced have less than the normal levels of Hb. [7][8] (U.S. Department of Health and Human Services, 2014). Ecuador has had a persistent problem with infant micronutrient deficiency in general and IDA in particular (Larrea & Kawachi, 2005; Farrow, et al., 2005; Larrea & Freire, 2002). In 1986 a diagnostic study on the nutritional health of children found that 69% of children 6 to 12 months and 46% of those 6 to 24 months had anemia (Freire, et al., 1988). Recently, the HNS of 2012 shows that anemia among children 6 to 12 months is still 62% and among those 12 to 23 months is 32%. Out of all the children between 6 and 59 months 26% are anemic in 2012 (Ministerio de Salud Publica; Instituto National de Estadisticas y Censos, 2013). Additionally, Ecuadorian chronic childhood malnutrition[9] was recorded at

[7] Iron-deficiency anaemia may develop over time as an iron deficiency will force the body to use its iron reserves. The consequential depletion and eventual exhaustion of iron reserves pushes the body to produce less blood cells and those which are produced have less than the normal level of Hb.

[8] Hb is an iron-rich protein that carries oxygen from the lungs to the rest of the body.

[9] For detailed explanation of this variable see Appendix 1.

40% in 1986[10], 34% in 2004[11] and 25% in 2006[12], however, the incidence has remained around 25% since (25% in 2012[13], and 26% in 2014[14]) (Ministerio de Salud Publica; Instituto National de Estadisticas y Censos, 2013).[15]

Previous studies on the effectiveness of nutrition supplementation programs on iron levels or anemia in children are scarce. They include clinical trials and large-scale programs. Clinical trials (in Latin America) tend to examine small samples and find positive effects. For instance, Silva et al. (2002) run a randomized-control trial on 89 pre-school children in Brazil and find that iron fortified milk beverage with probiotic bacteria helps preventing IDA by increasing the children's iron stores.[16] Large-scale public health programs differ from these small trials in important aspects. They analyse larger samples, which are often representative of the population. This increases the external validity of the findings, relative to small-scale RCTs. Furthermore, RCTs can achieve full compliance in small samples. This, however, is not feasible with large-scale social programs like the Ecuadorian one we examine. Studies on large-scale interventions, thus, report intention-to-treat estimates, which consider the effect of non-compliance, and thus inform about the likely effects of implementing a real-scale program. As outlined in the Introduction, only few studies have been published about the effectiveness of large-scale programs on iron-deficiency anemia prevention (Zlotkin et al., 2005). In one of the few studies in Latin America, Rivera et al. (2010) report that a large-scale iron-fortified subsidized-milk program was effective at reducing the rates of anemia and iron deficiency in Mexican children during 12 months of implementation. The closest study to ours is Zlotkin et al., (2005), as they examine an IDA-reducing public health intervention that also administered the micro-nutrients via "sprinkles", like our Ecuadorian intervention, to 15,000 children in Mongolia. They find that in the project area, prevalence of anemia is reduced to half pre-program levels.

Cash transfer programs have been widely used to treat nutrition deficiencies. Manley et al. (2013) perform a meta-analysis of the effect of cash transfer programs on nutritional status of children where they include

[10] As measured by the Encuesta Nacional de la Situación Alimentaria, Nutricional y de Salud de la Población Ecuatoriana Menor de Cinco Años also known as the 1986 DANS.
[11] As measured by the Encuesta Demografica y de Salud Materna e Infantil also known as the 2004 ENDEMAIN.
[12] As measured by the Encuesta de Condiciones de Vida also known as the Living Standards Measurement Survey or the 2006 LSMS. All estimation form HNS 2012 report except for the estimations of the LSMS of 2006 and 2014 which were made by the author.
[13] As measured by the Encuesta Nacional de Salud y Nutrition referred to it in this paper the national Health and Nutrition Survey or the 2012 HNS.
[14] As measured by the Encuesta de Condiciones de Vida also known as the Living Standards Measurement Survey or the 2014 LSMS. All estimation form HNS 2012 report except for the estimations of the LSMS of 2006 and 2014 which were made by the author.
[15] All estimation form HNS 2012 report except for the estimations of the LSMS of 2006 and 2014 which were made by the author.
[16] We do not include here the many correlational studies, e.g. Torrejon et al. (2004), that can be found in epidemiology.

21 studies and 17 programs. They find the programs' average impact on height for age is positive but not statistically significant. Most of the literature regarding public policy evaluation in Ecuador test the effect of conditional cash transfer programs on a range of health indicators (Manley, et al., 2013). Ponce and Bedi (2010) test the effect of the cash transfer called Bono de Desarrollo Humano on children's cognitive achievements. They use a RD strategy to identify the impact of the program on second graders and find no significant effect (Ponce & Bedi, 2010). Leon and Younger (2007) evaluate the effect of the transfer payment scheme called Bono Solidario in Ecuador on a child's nutritional status. They find that this cash transfer payment scheme has a significant effect on a child's nutritional status (Leon & Younger, 2007). Fernald and Hidrobo (2011) evaluate the effect of the Bono de Desarrollo Humano on health and development outcomes such as language shills, the z-score of height for age and Hb concentration in children between 12 and 35 months. They found significant effects on language development however not for children living in urban areas and no significant effect on the z-score of height for age or on Hb concentration (Fernald & Hidrobo, 2011). Hidrobo (2014) studies the effect of the 1999 Ecuadorian economic crisis on health and receptive language data for children 0 to 5 years old. Results suggest that a single year of exposure to the crisis significantly decreases the z-score of height for age and vocabulary test scores (Hidrobo, 2014). Schady (2012) studies the effect of cash transfers (Bono de Desarrollo Humano) on anemia in women of reproductive age and find mixed results (Schady, 2012). Carranza Carona and Mendez Sayago (2014) study the effect of this cash transfer on exclusive breastfeeding practices in Ecuador and find no significant effect (Carranza Baron & Mendez Sayago, 2014). Our paper examines for the first time the impact of a non-cash micronutrient supplement transfers on Hb levels in children in Ecuador.

3. The Program, data issues and empirical strategy

The supplement known as "sprinkles" is a blend of micronutrients distributed as a powder in small envelopes. "Sprinkles" were developed to prevent and treat micronutrient deficiencies among young children. One envelope contains 12.5mg of iron, 5mg of zinc, 160µg of folic acid, 300µg RE of vitamin A, and 30mg of vitamin C. The administration of 60 doses in 60 days is sufficient to quickly improve the concentration and deposits of Hb and iron in the blood. The sprinkles do not require a change of food consumption behaviours on the part of the family, they do not require any special measuring tools, they do not require the parents to be literate to be able to administer the dose, and they may be administered at any time during the day in any meal. They are encapsulated in lipids which prevents the interaction with food and masks the taste, consequently, there are minimal changes in taste, colour and texture of the food into which it is mixed. Notwithstanding, the supplement may cause constipation or diarrhea, particularly among younger children who have never had "sprinkles" before (Ministerio de Salud Publica, World Food Program, 2011).

3.1 National Iron Supplementation Programs

There are two national parallel programs currently distributing "sprinkles." The first program distributes supplements through the Ministry of Economic and Social Inclusion's (MIES[17]) public daycare centers (CIBV[18]) for children between 6 and 59 months.[19] For children who are not in daycare centers,[20] the MIES distributes "sprinkles" through house visits and group session program[21] (CNH[22]) (MCDS MIES INFA MSP MINEDUC, 2011).[23] The second program is coordinated through the Ministry of Public Health (MSP[24]) which distributes "sprinkles" and vitamin A to children between 6 and 24 months during their routine checkups (Ministerio de Salud Publica, World Food Program, 2011).[25]

Both of these programs are coordinated by the Ministry of Coordination of Social Development (MCDS[26]) which establishes the umbrella public policy denominated Childhood Development Strategy[27] in which children under 5 years of age are reported as the target demographic (Ministerio Coordinador del Desarrollo Social, 2011). We analyze both programs together.

3.2 The data

The National Health and Nutrition Survey (ENSANUT[28] which we refer to as HNS) is a cross-section dataset built by the National Institute for Statistics and Censes (INEC[29]) in Ecuador between 2011 and 2013. It covers various health topics including participation in public nutritional supplementation programs. It has a total sample of 92,502 individuals[30] out of which 11,506 are children under the age of 5, and 31,293 are children under the age of 10. There was a sub-sample of 21,482 individuals, out of which 2,047 were children between 6 and 59 months and 5,372 were children 10 or under who had blood samples taken and

[17] Given its name in Spanish: Ministerio de Inclusion Económica y Social.
[18] Well-being Childhood Centers given its name in Spanish: Centros Integrales del Buen Vivir.
[19] Administered by the caretakers at the daycares.
[20] Between 0 and 59 months.
[21] Administered in the context of the household by the parents.
[22] Growing with our Children given its name in Spanish: *Creciendo con Nuestros Hijos.*
[23] House visits are provided only for children between 0 and 12 months.
[24] Given its name in Spanish: *Ministerio de Salud Publica*.
[25] In this case, the doses are also given to the parents and administered by them in the context of the household
[26] Given its name in Spanish: *Ministerio Coordinador del Desarrollo Social.*
[27] In Spanish: *Estrategia de Desarrollo Infantil.*
[28] Given its name in Spanish: Encuesta Nacional de Salud y Nutrición.
[29] Given its name in Spanish: Instituto Nacional de Estadísticas y Censos.
[30] 19,949 households.

on which various biomarkers were measured including Hb (Ministerio de Salud Publica; Instituto National de Estadisticas y Censos, 2013).

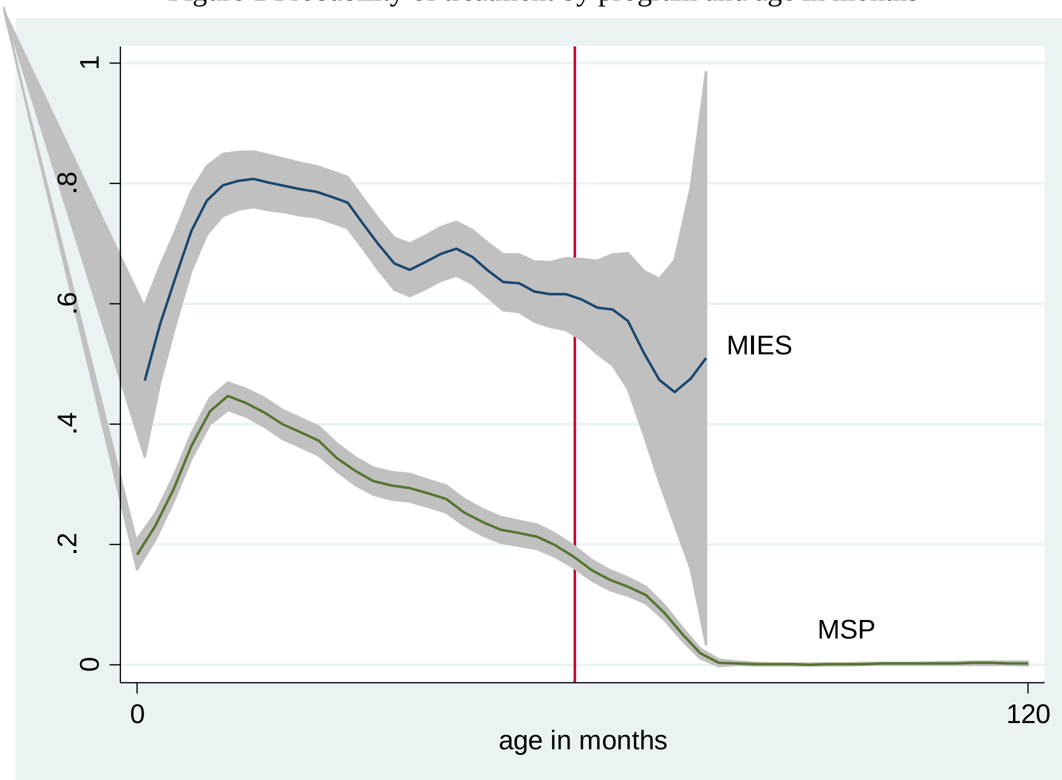
Hereafter, we will refer to the daycare program as the MIES program and the health center program as the MSP program.[31]

Since the MIES program administers the "sprinkles" at the daycare centre for children attending those centres, the children in the MIES program (blue) present a higher probability of receiving the treatment than the children in the MSP program (green) at any age (see Figure 1). The confidence interval among the children in the MIES program (blue) increases quite quickly after the 59-month cut-off point. This is due to the fact that the daycare centers only accept children up to 59 months old. As Table 1 show, the number of children still in daycare after 59 months is reduced to 114 children (6.2% of children in daycare).

As mentioned above, our sample includes children both in and out of daycare centers from both programs. Tables 1 and 2 show the distribution of treated and non treated children, below and above the age threshold that should apply to each program.

[31] Even though the house visits program is technically coordinated through the same ministry as the daycare centers. This is done because it is not possible to identify the source of the treatment, however, it is not known whether the child is attending a public daycare center or not. This allows us to differentiate the children who receive or might have received the treatment in daycare centers from the children who received it at home (through home visits or through their parents receiving the sachets at the healthcare center and administering it in the context of the household).

Figure 1 Probability of treatment by program and age in months



Source: Author's computation using 2012 Nutrition & Health Survey
MIES: Ministry of Economic and Social Inclusion's (MIES) public daycare centers (CIBV) for children between 6 and 59 months. For children who are not in daycare centers, the MIES distributes "sprinkles" through house visits and group session program (CNH) (MCDS MIES INFA MSP MINEDUC, 2011).
MSP: Ministry of Public Health (MSP) which distributes "sprinkles" and vitamin A to children between 6 and 24 months during their routine checkups (Ministerio de Salud Pública, World Food Program, 2011).

Table 1. Treatment by 59-month cut-off among children who go to daycare

	Not treated	Treated	Total
Over 59 months	49	65	114
59 or under	509	1,211	1,720
Total	558	1,276	1,834

Source: Author's computation using 2012 Nutrition & Health Survey

Table 2. Treatment by 24-month cut-off point among children out of daycare

	Not treated	Treated	Total
Over 23 months	14,351	1,805	16,156
23 or under	2,552	1,495	4,047
Total	16,903	3,300	20,203

Source: Author's computation using 2012 Nutrition & Health Survey

Table 3. Treatment by 59-month cut-off point among children out of daycare centers

	Not treated	Treated	Total
Over 59 months	10,594	366	10,960
59 or under	6,309	2,934	9,243
Total	16,903	3,300	20,203

Source: Author's computation using 2012 Nutrition & Health Survey

Table 4. Treatment by 36-month cut-off point among all children

	Not treated	Treated	Total
Over 36 months	13,454	1,804	15,258
35 or under	4,007	2,772	6,779
Total	17,461	4,576	22,037

Source: Author's computation using 2012 Nutrition & Health Survey

Table 5. Treatment by 59-month cut-off point among all children

	Not treated	Treated	Total
Over 59 months	10,643	431	11,074
59 or under	6,818	4,145	10,963
Total	17,461	4,576	22,037

Source: Author's computation using 2012 Nutrition & Health Survey

Table 6. Treatment by interval between 59 and 71 months among all children

	Not treated	Treated	Total
59 or under	6,945	4,184	11,129
Between 59 - 71	1,895	351	2,246
Over 71 months	8,621	41	8,662
Total	17,461	4,576	22,037

Source: Author's computation using 2012 Nutrition & Health Survey

3.3 Choosing the cut-off

Identifying where the exogenous discontinuity ought to take place is key in both an RD design and an IV model, as the cut-off is the instrument. Our choice of setting the cut-off at 71 months is guided by two elements. The umbrella MCDS program administers "sprinkles" to children smaller than 5 years (i.e. up to 59 moths). However, we do use the age of 59 months as our cut-off because the question asks about having received treatment in the 12 months previous to the interview. The question reads as follows (our own translation):

> "In the past 12 months from …[month beginning of period] to …[month of end of period] (…[Name of member of household]) is receiving or has received [during this period] benefits through the Nutritional Supplement Program (Sprinkles, iron, vitamin

A, folic acid) FREE OF CHARGE FROM THE STATE [National government]?"[32] (Ministerio de Salud Publica; Instituto National de Estadisticas y Censos, 2013)

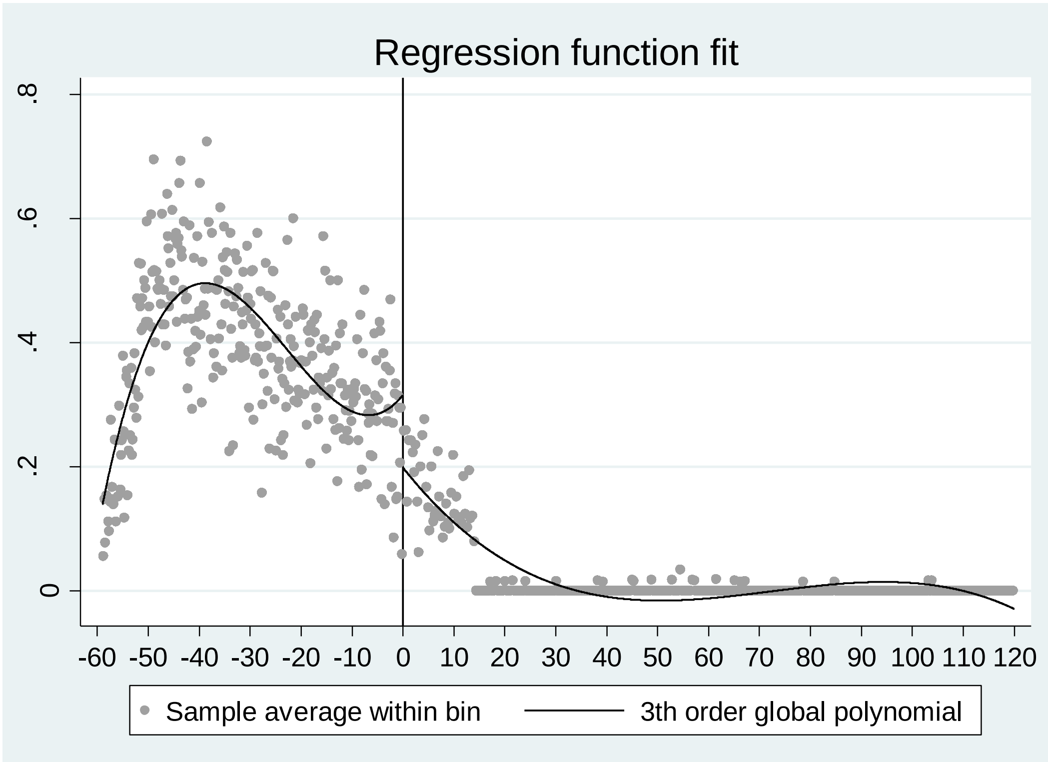
The fact that the question inquires on whether the child received treatment over the last twelve months directly affects the cut-off limit as it too is measured in age in months. For example, a child who is 71 months old (11 months older than the cut-off of 59 months) who received the treatment at the age of 59 months (11 months before the survey) will answer yes to this question despite being over the cut-off. This will happen without this representing a lack of enforcement of the cut-off. Similarly, a child who was 71 months old (11 months older than the cut-off of 59 months) and received the treatment at the age of 60 months (10 months before the survey) will also answer yes to this question and this will represent a lack of enforcement of the cut-off.

Therefore, it can be said that all the children who answer yes to this question up to the age of 71 months were potentially under the cut-off when they received the treatment. However, we cannot identify those who were and those who were not. Figures 2 and 3 show the probability of treatment that come from the data (partitioned in bins to reduce noise and improve clarity) and the fit of a kernel-weighted local polynomial regression on either side of the 59- and 71-month cut-off, respectively. Figure 3 shows that the probability of receiving the treatment falls to zero at 71 months, while this is not so in Figure2. Had there been no regard for the age cut-off, there would be no visible jump in the probability of receiving treatment at any age, let alone exactly 11 months after the age limit. We believe this jump is due precisely to the formulation of the question which stipulates participation over the last 12 months. Therefore, we assume 71 months accurately measures the cut-off point given the formulation of the survey question.

Note that Figure 3 illustrates the effect of our instrument, the cut-off, on the endogenous probability of treatment.

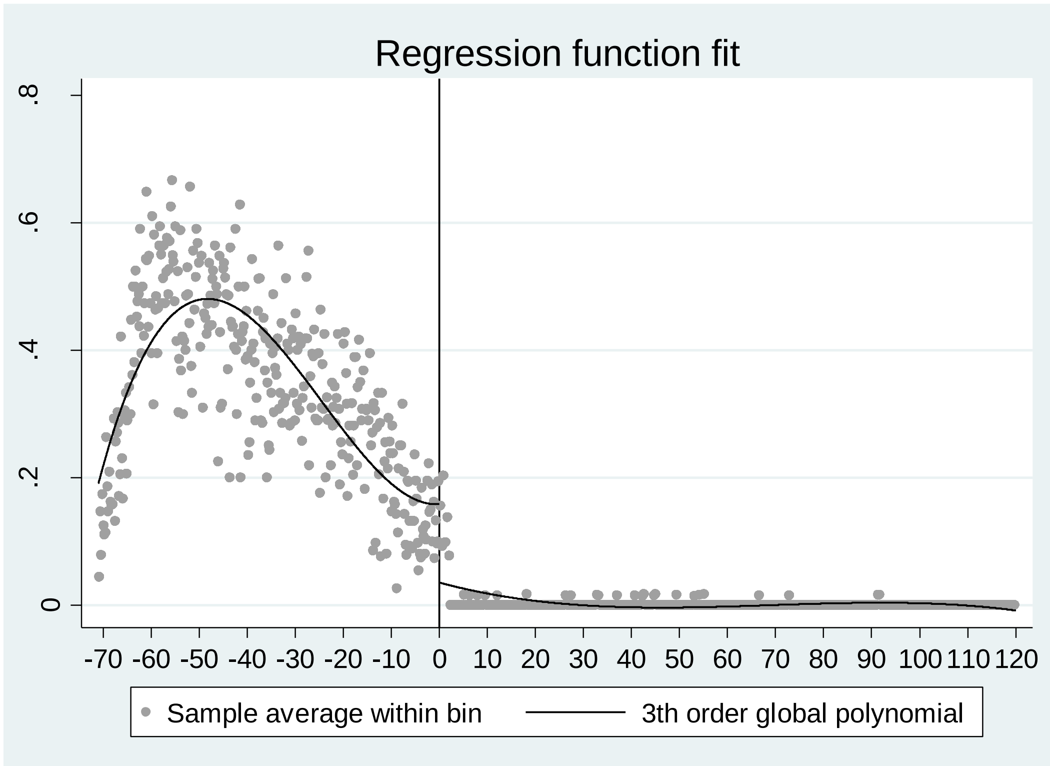
[32] Text as it is written literally in survey in Spanish: "¿Durante los últimos 12 meses de …………. a ……….. (…) recibe o recibió beneficios por el Programa Suplemento Nutricional (chispaz, hierro vitamina A, ácido fólico) GRATUITO, DEL ESTADO?"

Figure **¡Error! No hay texto con el estilo especificado en el documento.**. Probability of treatment by cut-off point, 59 months



Source: Author's computation using 2012 Nutrition & Health Survey

Figure 3. Probability of treatment by cut-off point, 71 months



Source: Author's computation using 2012 Nutrition & Health Survey

According to some information that appears in administrative documents from the Ministries involved in the two programs, there are two age thresholds that need to be discussed. First, some administrative documents suggest that the cut-off point for the MSP program is 24 months (Ministerio de Salud Publica, World Food Program, 2011). Contrary to this, however, most of the children not in public daycare centers who receive the treatment through the MSP program are over the age of 24 months, as Table 2 shows. Additionally, most of the children not in public daycare centers who receive the treatment through the MSP program are under the age of 59 months, as Table 3 shows. Therefore, it seems that, in practice, the eligibility rule that is adhered to is the umbrella MCDS program cut-off point of 59 months.

Second, after 2013, some documents advocated changing the public policy eligibility rule from 59 to 36 months (Ministerio de Inclusion Economica y Social, 2013).[33] As Table 4 shows, a very large proportion

[33] As of October 2012, a statement (Ministerio de Inclusión Económica y Social, 2013) made by the head of State (President Rafael Correa) demonstrated a political will to change the public policy regarding eligibility by age from children under 59 to children under 36 months. The changes in the public policy literature began to appear in 2013 (Ministerio de Inclusión Económica y Social, 2013; Ministerio de Inclusión Económica y Social, 2013). Despite the survey being executed between 2011 and 2013 (Ministerio

of the pooled sample of children from both MIES and MSP programs who receive the treatment are over 36 months. Table 5 shows that the majority of children from the pooled sample who receive the treatment are under the age of 59 months. Therefore, it seems that this change in policy was not yet in place during the 2012 HNS.[34] Table 5 also indicates that this is clearly not a deterministic eligibility rule. Therefore, as we explain below, we use a fuzzy RD design and an IV model to estimate the program effects.

The outcome variable: Hemoglobin

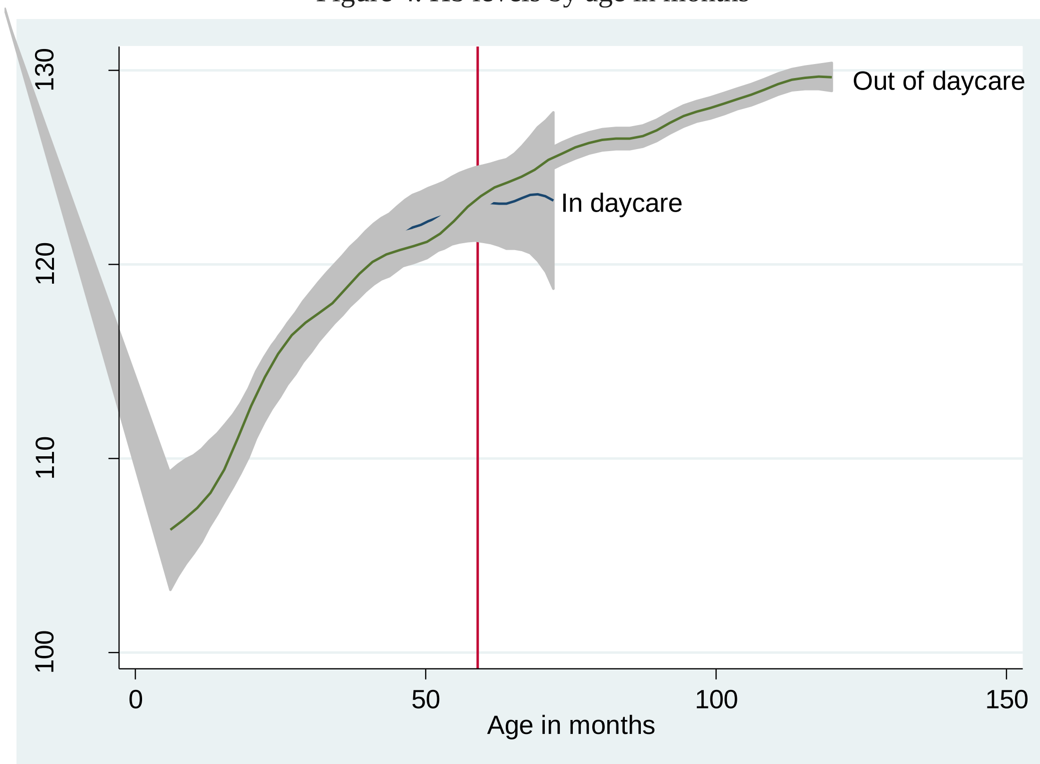
The Hb measured in the survey is corrected for the altitude of the place of residence of the child. Altitude has been recognized to have an effect on Hb levels and on the red blood cell count. Specifically, a decline in oxygen partial pressure that occurs as altitude increases is normally associated with a decline in the oxygen saturation of arterial blood and an increased concentration of Hb. In the case of the children in the 2012 HNS the altitude ranges from 0m to 3834m above sea level. Andean highlanders, such as those participating in these projects, who are exposed to high altitudes are generally characterized by high concentrations of Hb relative to individuals who live at sea level. This has been considered an adaptive response which allows the individual to maintain their oxygen supply under conditions of arterial hypoxia. This phenomenon can lead to an underestimation of the prevalence of IDA at high altitudes. We apply the correction proposed by Diren et al. (1994) who estimated corrections for Hb by altitude using Ecuador as an example (Dirren, et al., 1994).

In Figure 4 the outcome, Hb, is shown in blue for the MIES program and in green for the MSP program with a red line at the cut-off point. Hb levels increase with age and that they are fairly similar across the two groups of children. In order to control for the effect of age we will make the bandwidth around the cut-off point as small as possible.

de Salud Publica; Instituto National de Estadísticas y Censos, 2013), the data indicates that these changes seemed to not yet be underway while the survey took place.

[34] The National Health and Nutrition Survey (ENSANUT, which I refer to as HNS) is a cross-section database built by the National Institute for Statistics and Censes (INEC) in Ecuador between 2011 and 2013.

Figure 4. Hb levels by age in months



Source: Author's computation using 2012 Nutrition & Health Survey

3.4 Empirical Strategy

To estimates the effect of the nutritional supplementation program, we use Fuzzy RD and IV methods, which address the non-compliance issues related to the implementation of the program. First, the program did not monitor the correct and complete administration of all doses included in the program. Furthermore, the 2012 HNS does not provide information on the number of doses received by the children. Therefore, we are unable to discern if they completed the treatment or not. This implies that we are testing the effect of the treatment on a sample of children who participated and received at least one dose in the past 12 months without knowing if they complied with the full treatment.

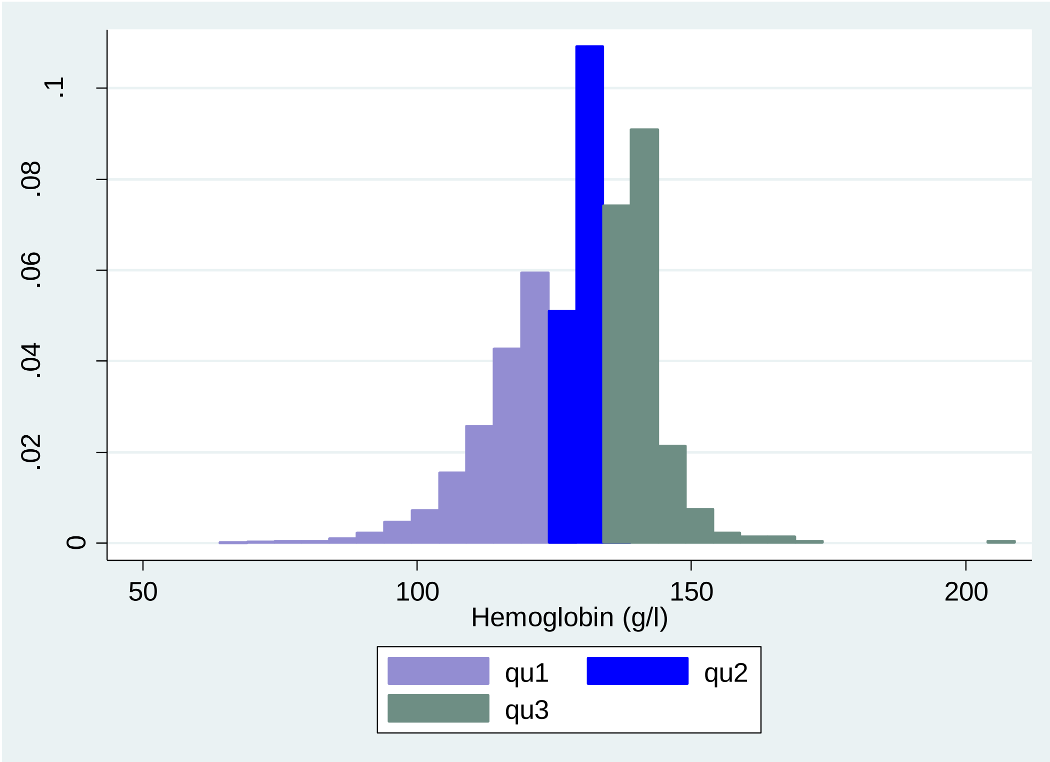
Second, we also have some uncertainty about the type of supplement administered to children. The question asks if any member of the household received either "Sprinkles, iron, vitamin A or folic acid" (Ministerio de Salud Publica; Instituto National de Estadisticas y Censos, 2013). Positive answers to this question may include mothers who received folic acid. By isolating the sample to children, we can effectively eliminate the mothers who received folic acid.

However, the MSP does distribute vitamin A separately in the form of pills. Notwithstanding, the literature suggests that vitamin A deficiency is treated firstly with “sprinkles,” as they contain 300µg RE of vitamin A, and, if necessary, to be used simultaneously with the pills which have “mega-doses” of vitamin A (15015,015µg RE) (Ministerio de Salud Publica, World Food Program, 2011).[35] Given there is no way to discern the exact source of the micronutrients and given the available information on treatment protocols we are assuming the children who answered yes to this question effectively received “sprinkles” (Ministerio de Salud Publica; Instituto National de Estadisticas y Censos, 2013).

Therefore, our running variable does not have a deterministic relationship with treatment, but only a probabilistic one. We use the cut-off as instrument, which affects the probability of treatment, as Figure 3 shows, and then examine the relationship between treatment and the outcome variable, hemoglobin with a Fuzzy RD design and an IV regression. Both methods yield local average treatment effects on the compliers. The main difference between the fuzzy RD model and the IV model is the width of the bandwidth around the cut-off used for the analysis. While the former identifies the effect by comparing Hb levels of children who are barely younger and barely older than the cut-off age, IV methods estimate the impact of the program on all the treated children, including the ones who are “far” from the cut-off. We thus face the standard efficiency-bias trade off. The IV model will allow us to examine whether the program effect is different for children with different levels of Hb, something we cannot do with the RD because of the reduced sample size around the cut-off. To this end we partition the sample into three groups: a first one includes children with low Hb levels (lower than 125 g/l), a second one includes children with medium levels of Hb (between 126 to 135 g/l), and a third group includes children with high levels of Hb (higher than 135 g/l). Figure 5 shows the density of Hb and the relative frequency of each one of the three groups.

[35] Given the MSP distributed iron and vitamin A supplements freely to all children under the age of 24 months, the daycare center sample may be composed of children who also received vitamin A on a routine checkup.

Figure 5 Distribution of Hb (g/l) among children < 120 months



Source: Author's computation using 2012 Nutrition & Health Survey

4. The results

4.1 Regression discontinuity

The descriptive statistics of the variables used in the RD model are presented in Table 7.

Table 7. Descriptive statistics of variables used in RD models i.e. children under the age of 10

Variable	Obs	Mean	Std. Dev.	Min	Max
Hb g/l	5,286	122.8	11.18	64	208
D. Treatment	22,211	0.2	0.4	0	1
D. 59 months or under	22,519	0.5	0.5	0	1
D. 71 months or under	22,519	0.6	0.5	0	1
Age in months	22,519	59.42	35.17	0	120

Source: Author's computation using 2012 Nutrition & Health Survey

Table 8 presents linear, quadratic and cubic models with robust confidence intervals, as proposed by Calonico et al. (2014). This estimation is presented for various bandwidths around the cut-off point which in our case is measured in age in months. For example, a bandwidth of 2 would include children 2 months younger and 2 months older than 71 months. Recall that given the effect of age on Hb levels, the smallest bandwidths yield the least biased estimates.

Table 8 shows suggests that on average the program had no effect on Hb levels, as none of the estimates is significant. Notwithstanding, it is important to note that the size of our estimates are within a reasonable range. For instance, the coefficient estimate of -8.26 in the linear model for the one-month bandwidth implies a reduction in levels of Hb of around 8 g/l, Now, minimum non-anaemic levels of Hb for children from 6 to 59 months of age is 110 g/l. Thus, the above estimate implies a reduction in Hb levels lower than 10%.

Notice also that the sign of the estimated coefficients is not stable for different bandwidths and across the three specifications. For instance, it is mostly positive in the linear model, but mostly negative for the quadratic and cubic models. Such instability is also suggestive that the true effect is likely to be nil.

Table 8. Effect of the program on children's Hb levels. Fuzzy RD estimates.

Bandwidth	Left	Right	Linear		Quadratic		Cubic	
			Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
1 month	38	49	-8.26	10.41	-6.77	13.57	-3.48	13.25
2 months	93	93	-3.10	10.34	-4.85	9.55	-8.30	11.67
3 months	145	141	0.38	14.00	-3.32	9.07	-7.26	10.52
4 months	193	189	0.32	18.40	-0.87	10.68	-4.68	9.01
3 months	241	229	1.87	18.51	-1.43	14.36	-2.37	8.96
6 months	297	286	1.34	17.69	0.72	17.42	-2.26	10.70
7 months	348	334	4.14	17.19	-1.80	18.58	-0.34	12.98
8 months	401	375	5.88	16.32	-2.17	19.08	-0.79	15.03
9 months	453	419	6.69	16.98	0.81	17.89	-3.83	17.58
10 months	496	479	4.19	15.77	6.40	19.78	-6.01	17.66
11 months	540	513	1.82	15.48	9.06	20.49	-4.73	18.58
12 months	602	541	0.05	14.75	9.09	19.92	-0.63	18.18

Source: Author's computation using 2012 Nutrition & Health Survey

4.2 Instrumental variables

In this section we report the IV estimates, which identify effect of treatment from a sample which includes children who are "further" from the cut-off point than the sample used in the RD analysis above. Descriptive statistics for the variables used in the IV models are shown in Appendix 2 Table A1.

Table 9 displays estimates of the second stage regression for the homogeneous and heterogeneous effect models. The estimated impact that obtains from the homogeneous effect model is four times smaller than the RD estimated effect and not statistically significant. Taken at face value, the smaller IV estimate may suggest that the negative effect of the program fades away as children are further away from the cut-off, that is, as they are older —however, the RD estimates of any of the three specifications do not increase monotonically as the bandwidth is increased. Now, as outlined above, the further away from the cut-off we move, the more likely is that our IV estimate captures the positive effect of age on Hb levels, in addition to the true program effect. This means that our IV estimate is biased upwards, i.e. that the true impact of the program is more negative than the size of the IV estimate. This possible bias thus reinforces that idea pointed out above that the effect of the program fades away as children are further away from the cut-off.

The second set of columns of Table 9 displays the estimates from the heterogeneous effect model. To estimate the effects of the program for different levels of Hb, we interact the treatment dummy with two dummies indicating whether the children belongs to the low and to the high Hb levels described in the previous section. Since we now have tree endogenous variables, i.e. the treatment dummy and the two interaction terms, we need three instruments. Hence, in addition to the cut-off, which was our instrument in the homogeneous model, we also use the interaction between the cut-off, on the one hand, and middle and high Hb level group dummies, on the other (Cerulli, 2012).

The first thing worth noting is that the average nil effect we found in the homogeneous model conceals significant effects at different Hb levels that cancel out. The estimate in the first row shows that the impact of the program for the middle Hb level group (our reference group in the specification) is positive and significant. The program improves Hb levels of initially compliers with middle Hb levels by 5.8 g/l. The point estimate of the effect of the program for the high Hb level group would suggest that the program has no effect on this group, as the size of the effect is almost the same as the base effect with the opposite sign. However, the estimate is not precisely estimated at all, which suggests that the impact of the program is the same for the high than for the middle Hb level groups. Finally, our results suggest that children with low Hb levels see their Hb levels reduced by the impact of the program, and the reduction is sizeable, 10.8 g/l. This might be a consequence of diarrhea caused by the treatment and/or a failure to comply with the total needed doses.

Other than the program, the heterogenous effects model suggest that children in extreme poverty and from indigenous families have on average lower Hb levels while children whose mother has higher levels of education have higher Hb levels. Relative to the effect of these covariate, the positive effect of the program on children with meddle and high Hb levels is sizeable, as it doubles the effect of belonging to an indigenous family, which is the largest effect of all covariates.

Table 10 shows the first stage regressions. The first pair of columns shows estimates of the first stage of the homogeneous effects, where the highly significant instrument is the dummy treatment using the cut-off (dummy child under 71 months of age). Since the heterogeneous effects model has two interaction terms, , it has three endogenous variables: (1) the dummy treatment, (2) the interaction between the dummy treatment and the dummy indicating low Hb, and (3) the interaction between the dummy treatment and the dummy indicating high Hb. We thus need three instruments, which are (1) the dummy cut-off, (2) the interaction between dummy cut-off and the dummy indicating low Hb, and (3) the interaction between dummy cut-off and the dummy indicating high Hb. The three first stage regressions for each of these three endogenous variables are shown in the last three pair of columns of Table 10. The large F-value of the instruments indicate that they explain enough variability of the endogenous variable.

Table 9. Effect of the program on children's Hb levels. IV estimates.

	Homogeneous	Heterogeneous
	b(s.e.)	b(s.e.)
D. Treat	-2.03	5.75**
	(2.81)	(2.43)
D. Treat * Low Hb group		-16.57***
		(3.24)
D. Low Hb group		-10.2***
		(0.32)
D. Treat * High Hb group		-5.6076
		(11.5)
D. High Hb group		9.1169***
		(0.6)
D. Extreme poverty	0.7937	-0.2121***
	(0.88)	(0.64)
D. Daycare	-0.7847	-2.6499
	(1.89)	(1.63)
Z-score height-for-age	0.1782	-0.0585
	(0.25)	(0.16)
Age in months	0.4560***	0.3633***
	(0.03)	(0.03)
Age in months ^2	-0.0021***	-0.0019***
	(0.00)	(0.00)
D. Diarrhea	-0.1359	-0.26
	(0.7)	(0.53)
D. Female	0.8162*	0.3553
	(0.48)	(0.36)
Hb. mother	-0.9055***	-0.214
	(0.3)	(0.2)
Hb. mother ^2	0.0043***	0.0013
	(0.00)	(0.00)
Schooling mother	0.2530***	0.1423**
	(0.07)	(0.05)
D. Free maternal healthcare	-1.6833	-1.419
	(1.14)	(1.03)
D. Mother employed	-0.1149	0.5069
	(0.5)	(0.36)
Ln hh income pc	0.4509	-0.1735
	(0.43)	(0.31)
D. Indigenous	-3.4065***	-2.5806***
	(0.97)	(0.76)
D. Afro-Ecuadorian	-1.7952	-0.9389
	(1.58)	(1.23)
D. Montubio	0.8262	-0.3379
	(1.05)	(0.85)
D. Urban highlands	0.5757	-0.6239
	(1.4)	(1.21)
D. Rural highlands	1.1777	0.0061
	(1.44)	(1.19)
D. Urban coast	1.3877	0.6241
	(1.34)	(1.17)
D. Rural coast	0.1335	-0.284
	(1.53)	(1.3)
D. Urban amazon	1.2333	0.4041
	(1.55)	(1.28)
D. Rural amazon	1.2445	0.5496
	(1.57)	(1.27)
D. Galapagos	3.5439**	2.0132
	(1.74)	(1.36)
D. Guayaquil	1.7943	0.1551
	(1.57)	(1.38)
Constant term	142.9664***	119.4798***
	(19.53)	(13.1)
r2	0.5156	0.7295
N	1344	1344

Source: Author's computation using 2012 Nutrition & Health Survey

Table 10. First stage IV regressions

	Homogeneous		Heterogeneous Effects Model					
Endogenous	D.treat		D.treat		D.treat * D.Low Hb		D.treat*D.High Hb	
Instrument	D.71		D.71, D.71*D.Low Hb, D.71*D.High Hb					
F-value	28.74		24.87		27.04		17.00	
F-value instruments	22.5		8.51		15.89		129.07	
	b	s.e.	b	s.e.	b	s.e.	b	s.e.
D. 71 months	0.156	(0.03)	0.129	(0.04)	-0.078	(0.04)	0.002	(0.00)
D. 71 months*D. Low Hb			0.027	(0.04)	0.271	(0.04)	0.003	(0.00)
D. 71 months*D. Low Hb			0.180	(0.10)	0.070	(0.10)	0.324	(0.01)
D. Low Hb group			-0.005	(0.02)	0.000	(0.02)	-0.002	(0.00)
D. High Hb group			0.000	(0.03)	-0.003	(0.02)	0.007	(0.00)
D. Extreme poverty	0.008	(0.02)	0.007	(0.02)	0.000	(0.02)	0.008	(0.00)
D. Daycare	0.299	(0.04)	0.300	(0.04)	0.250	(0.03)	0.000	(0.00)
z-score height-for-age	0.005	(0.00)	0.004	(0.00)	0.002	(0.00)	0.000	(0.00)
Age (months)	-0.005	(0.00)	-0.005	(0.00)	-0.004	(0.00)	0.000	(0.00)
Age^2 (months)	0.000	(0.00)	0.000	(0.00)	0.000	(0.00)	0.000	(0.00)
D. diarrhea	0.036	(0.02)	0.035	(0.02)	0.019	(0.02)	0.003	(0.00)
D. female	-0.007	(0.01)	-0.006	(0.01)	-0.011	(0.01)	0.001	(0.00)
Hb mother	0.009	(0.01)	0.009	(0.01)	0.007	(0.00)	0.001	(0.00)
Hb^2 mother	0.000	(0.00)	0.000	(0.00)	0.000	(0.00)	0.000	(0.00)
Schooling mother	-0.001	(0.00)	-0.001	(0.00)	-0.002	(0.00)	0.000	(0.00)
D. free maternal healthcare	0.129	(0.03)	0.129	(0.03)	0.110	(0.03)	0.001	(0.00)
D. mother employed	-0.003	(0.01)	-0.003	(0.01)	-0.001	(0.01)	-0.001	(0.00)
Ln(hh income pc)	0.020	(0.01)	0.020	(0.01)	0.016	(0.01)	0.004	(0.00)
D. indigenous	-0.008	(0.03)	-0.008	(0.03)	0.001	(0.02)	0.000	(0.00)
D. afro-ecuadorian	-0.047	(0.04)	-0.045	(0.04)	-0.032	(0.04)	0.000	(0.00)
D. montubio	0.034	(0.03)	0.033	(0.03)	0.013	(0.03)	-0.009	(0.00)
D. urban highlands	0.075	(0.04)	0.075	(0.04)	0.093	(0.04)	-0.034	(0.00)
D. rural highlands	0.144	(0.04)	0.146	(0.04)	0.149	(0.04)	-0.029	(0.00)
D. urban coast	0.003	(0.04)	0.004	(0.04)	0.028	(0.04)	-0.028	(0.00)
D. rural coast	0.068	(0.04)	0.070	(0.04)	0.093	(0.04)	-0.021	(0.00)
D. urban amazon	0.140	(0.04)	0.142	(0.04)	0.167	(0.04)	-0.030	(0.00)
D. rural amazon	0.112	(0.04)	0.115	(0.04)	0.130	(0.04)	-0.030	(0.00)
D. Galapagos	0.028	(0.05)	0.028	(0.05)	0.062	(0.05)	-0.037	(0.00)
D. Guayaquil	-0.040	(0.05)	-0.036	(0.05)	-0.007	(0.04)	-0.028	(0.00)
Constant term	-0.502	(0.63)	-0.498	(0.63)	-0.449	(0.59)	-0.102	
R2	0.353		0.354		0.374		0.273	
N	1344		1344		1344		1344	

Source: Author’s computation using 2012 Nutrition & Health Survey

In summary, the average effect is not significant and seems to have a positive coefficient in the RD model while having a negative one in the IV model. The negative sign in the IV model seems to be driven by the effect on the group where children have the lowest Hb levels. Here, we find a negative significant effect. The rest of children with higher Hb levels seem to benefit from the program. The negative significant effect of the low Hb group may be driven by diarrhea caused by the treatment and/or by a lack of compliance in the number of doses as this is not measured in this model.

5. Conclusion

IDA is a condition characterized by a depletion in iron reserves leading to a lower than normal level of Hb in the blood (U.S. Department of Health and Human Services, 2014).[36] It is a form of malnutrition which has the potential to affect development, learning abilities and schooling achievements in children (Martinez, et al., 2009; WHO, 2015; Micronutrient Initiative, 2015). Ecuador is an important case study for the evaluation of public policy to reduce IDA as it has had a persistent problem with the incidence of IDA among children[37] (Freire, et al., 1988; Ministerio de Salud Publica; Instituto National de Estadisticas y Censos, 2013).

This study is an evaluation of the public policy attempting to reduce the prevalence of IDA in Ecuador. We evaluate the national program that distributes micronutrient supplements through both public daycare and public healthcare centers. The policy stipulates that children up to the age of 59 months are eligible for the treatment. Children over this age are no longer eligible.

We use the 2012 cross-section HNS where there is information both on Hb levels of children and whether they received the treatment in the past 12 months. In order to identify the causal effect of the intention to treat, we present two methods: Firstly, a fuzzy RD model in which we use the age eligibility rule as a cut-off point, and, secondly, an IV model in which we use the age eligibility rule as an instrument. Additionally, we study heterogeneous effects by levels of the dependent variable Hb.

Both methods allow us to exogenously identify participants from non-participants and account for observed as well unobserved heterogeneity. Both models allow for endogeneity in both individual participation and program placement by identifying a cut-off or instrument that is highly correlated with program placement and not correlated with the unobserved characteristics affecting outcome. The difference between these two methods lies in the bandwidth around the cut-off used. In the fuzzy RD model, this bandwidth restricts the sample of both treatment and control groups to children who are 'close' to the cut-off age while the IV model measures the effect on all children from 6 to 120 months.

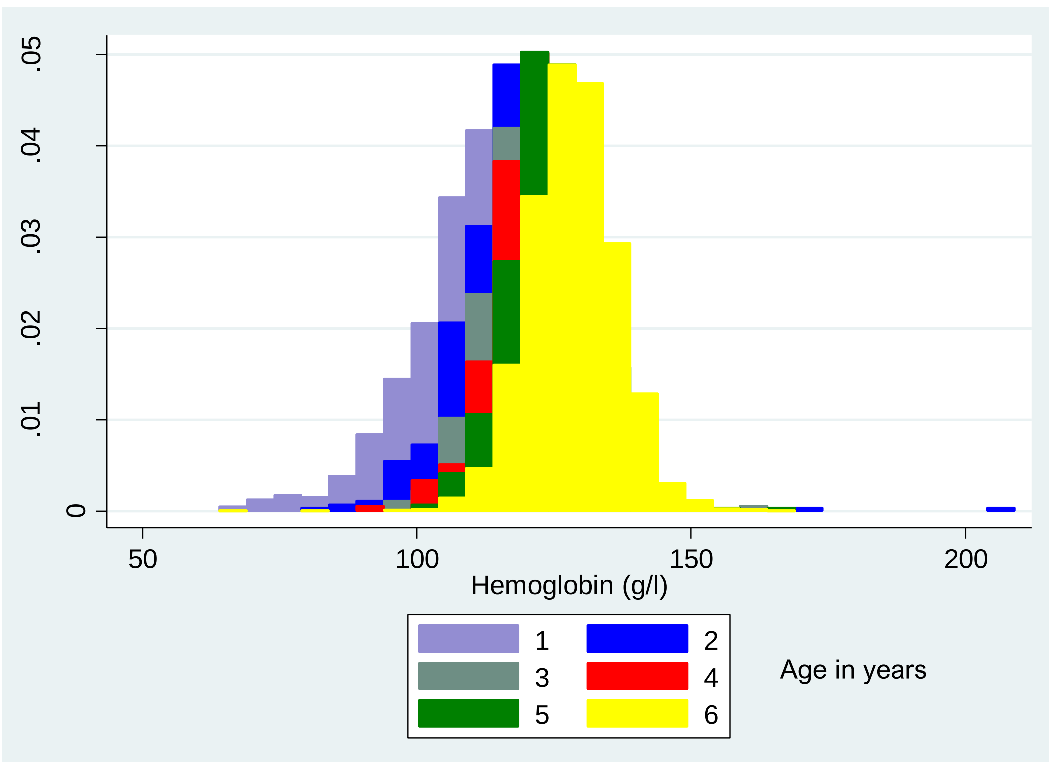
Despite specifying various bandwidths and functional forms, our results show no significant effects in the fuzzy RD models with some specification resulting in positive and others in negative coefficients. The average effect of the IV model is negative and non-significant, however, when heterogeneous effects are introduced, we uncover that such nil effect conceals effects of opposed signs for low Hb children, whose

[36] Hb is an iron-rich protein that carries oxygen from the lungs to the rest of the body.
[37] 69% in 1988 and 62% in 2012 among children 6 to 12 months of age.

Hb levels decrease as a result of the program, and for high Hb children, whose Hb levels increase as a result of the program. Further research is needed to identify the effect by dose and the effect on children who get severe diarrhea as a consequence of the treatment, as we suspect attrition and diarrhea might be driving the negative effect.

Our analysis of the heterogeneous effect by Hb levels indirectly informs about the heterogeneous effect by age, as children under the age of 1 tend to be in the lower end of the Hb distribution (Figure 6). Obviously, we are controlling for the effect of age, and any other contemporaneous factor affecting IDA. However, younger children in the lower end of the distribution may help explain the negative significant effect in the first quantile, as it is more likely that younger children have never had the treatment before. If the treatment causes diarrhea, particularly among children who have never had "sprinkles" before, then it would show up as a negative effect of the intention to treat (Ministerio de Salud Publica, World Food Program, 2011).

Figure 6. Distribution of Hb by age in years



Source: Author's computation using 2012 Nutrition & Health Survey

We are not able to include heterogeneous effects in the RD model given the bandwidth around the cut-off needs to be very small and this reduces the sample size considerably. At the smallest bandwidth of 1 month the sample size is 38 for the treatment and 49 for the control, at the largest bandwidth of 12 months, the sample is 602 for treatment and 541 for control. In order to have heterogeneous effects, we would need to run a model with a considerably larger bandwidth, which, if taken to the extreme of including all children, would be methodologically equivalent to running an IV model[38] (Calonico, et al., 2014).

We believe this study is an important contribution to the literature as it identifies the causal effect of the intention to treat and it is the first to evaluate a non-cash transfer on the nutritional health of children in Ecuador. Most studies relating to the nutritional health of children in Ecuador use similar techniques to identify the causal effect of the treatment, however, they mainly study the effect of the national wide cash transfer program called “Bono de desarrollo humano,” others study the effect of the Ecuadorian 1999 financial crisis on nutritional outcomes and most use the z-score of height for age as the outcome variable. There are no studies, to our knowledge, which study non-cash transfer program such as nutritional supplements on the nutritional outcome of children. Furthermore, there are virtually no studies that use blood sample outcomes such as Hb as outcome variables. Rather, most focus on the anthropometric outcomes that are more widely available.

[38] Given it is constructed in a twostep process: the first stage is the regression where the cut-off predicts the treatment and the second is the regression where predicted treatment predicts the outcome (the estimand takes the form of a ratio of the two).

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Appendix 1. Chronic child malnutrition and the z-score of height-for-age

The z-score of height-for-age is estimated using the methodology developed and distributed freely by the World Health Organization (2013). The normalized z-score (equation A.1) establishes the growth standard of children by defining a normal growth curve (World Health Organization, 2013; World Health Organization, 1997).

$$z\ score = {(x_i - x_{median})}/{\sigma^x} \tag{A.1}$$

Where x_i is the height of child i, x_{median} is the median height from the reference population of the same age and gender and σ^x is the standard deviation of x of the same reference population (Imai, et al., 2014; World Health Organization, 1997). This score is generally estimated using anthropometric data available in the diagnosis of the nutritional and health situation of Ecuador (DANS[39]) survey 1986, LSMS (2006, 2014) and HNS for each child below the age of five. The z-score ranges from $-\infty$ to ∞ as it is measured in standard deviations from the mean which is zero. If a child's z-score is under -2, that is to say, under two standard deviations below the mean, the child is chronically malnourished or "stunted" (World Health Organization, 1997).

[39] For its name in Spanish: *Diagnóstico de la situación alimentaria nutricional y de salud*.

Appendix 2. Descriptive statistics of variables included in the IV models

Table A.1 Descriptive statistics of variables used in IV model i.e. children under the age of 10

	Obs	Mean	Std.Dev.	Min	Max
Hb (g/l)	5230	122.68	11.19	64	208
D. Treat	22037	0.2	0.4	0	1
Age in months	22344	59.43	34.89	0	120
Age in months 2	22344	4749.82	4325.47	0	14400
D. Diarrhea	10473	0.16	0.36	0	1
D. Public daycare	22037	0.08	0.27	0	1
D. Female	22344	0.49	0.49	0	1
Hb mother	8579	127.43	10.99	51	160
Hb mother 2	8579	16360.87	2666.36	2601	25600
Schooling mother	21193	8.68	3.98	0	20
D. access maternity healthcare	22037	0.12	0.32	0	1
D. mother employed	21041	0.45	0.49	0	1
Ln(income per capita)	21189	4.35	0.89	0	8.111727
D. Extreme poverty	22344	0.28	0.45	0	1
D. Indigena	22037	0.14	0.35	0	1
D. Afro	22037	0.04	0.2	0	1
D. Montubio	22037	0.02	0.16	0	1
D. Urban Highlands	22344	0.2	0.4	0	1
D. Rural Highlands	22344	0.19	0.39	0	1
D. Urban Cost	22344	0.13	0.33	0	1
D. Rural Coast	22344	0.06	0.24	0	1
D. Urban Amazon	22344	0.11	0.32	0	1
D. Rural Amazon	22344	0.17	0.38	0	1
D. Galapagos	22344	0.02	0.15	0	1
D. Guayaquil	22344	0.03	0.18	0	1
D. Under 71 months old	22344	0.6	0.48	0	1

Source: Author’s computation using 2012 Nutrition & Health Survey