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SOMMAIRE

A two-stage control function approach with settlement-specific residual variances to identify effects of family size on school achievement in Ouagadougou

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Abstract

In Ouagadougou (the capital of Burkina Faso), at least 33% of the 2.5 million inhabitants live in informal settlements, while the remainder lives in the formal settlements. The sub-population in the informal settlements lacks social infrastructure and has extremely low education attainments. Motivated by this specific context, we develop a method that can be used to investigate differences in family behaviour towards schooling in the two settlement types and, in particular, the trade- off between child quantity and quality. Our method uses a two-stage control function approach that allows for settlement-specific residual variances as well as for the endogeneity of both the number of children and the settlement choice. After controlling for a set of observable covariates, we find evidence of a significant non-linear quantity-quality trade-off in the informal settlements. We also find evidence that significant differences in quantity-quality behaviour exist between the two settlements, but that the differences depend on both the education outcome considered as well as the gender of the child.

Keywords : School Attainment, Family Size, Regional Disparities, Quantity-Quality trade-off, Burkina Faso, Control Function Approach.

JEL subject classification : I25, I24, J13, J16, J18, C36.

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1. Introduction

It is well-known that economic and population growth are concentrated within urban areas (United Nations 2012). This trend may result in better socio-economic indicators in urban areas versus the rest of the country. However, these indicators may also hide important inequalities in education accross sub-populations within urban areas. A broad review conducted by the National Research Council (2003) demonstrated that the urban poor in developing countries often face worse socio-economic conditions than the rural poor. Indeed, urban poverty is concentrated in slums, so the health risks faced by the urban poor might even exceed those in rural areas (see for instance Montgomery and Hewett (2005)). These socio-economic differences can have a tangible impact on the way families view trade-offs between family size and investment in child education.

In Ouagadougou, the capital of Burkina Faso, at least 33% of the population of 2.5 [1] million lives in informal settlements (Boyer and Delaunay 2009). These settlements lack social infrastructure such as health facilities, electricity, and drinking water networks. Further, literacy and educational rates tend to be much lower in the informal settlements relative to the formal settlements, and parents' occupations tend to be very different. These fundamental differences may lead to differences in household behaviour towards schooling between the two types of settlements.

[1] 2019 Burkina Faso's Census

The general objective in this paper is to test theory child quantity and quality trade-off (QQ trade-off) of Becker and Lewis, 1973 in a heterogeneous population context. Specifically, we seek to answer the following questions :

- Is there an endogeneity between family size and children schooling in the two types of settlements in Ouagadougou?
- Is there a child quantity and quality trade-off in the two types of settlements in Ouagadougou? If yes, what is the nature of this link?

Answering the first question will allow us to know if families are making family planning decisions based on desired level of per-child human capital investment in the two settlements types. The second question, on the other hand, will allow us to know how family size affects children's schooling. To answer these questions, our method uses a two-stage control function approach that allows for settlement-specific residual variances as well as for the endogeneity of both the number of children and the settlement choice.

The remainder of this paper is organized as follows. In the following section, we briefly describe the context and the literature review. Section 3 presents the data and the empirical specification. Section 4 presents the estimation procedure and the results, and section 5 concludes.

2. Context and literature review

Two types of population compose the city of Ouagadougou. These are the population in the formal settlements and those in the informal settlements commonly referred to "unplanned areas". Unlike formal settlements, the inhabitants of the informal settlements seem to be younger with less educated population. In term of families' characteristics, we note that informal settlements lack of baseline socio-economic conditions. For instance, there is not an electricity network in the informal settlements, and almost all families use oil lamps or flash- lights as sources of light. A few number of the population use solar electricity. In terms of drinking water, the majority use uses a public fountains. In sum, these informal setttlemts are made up of a majority of poor compared to the formal settlement[2]. These fundamental differences may lead to differences in household behaviour towards schooling and family size between the two types of settlements.

Motivated by this context, we aim to develop a method that can be used to study disparities in the trade-offs made between child quantity and quality (QQ) (Becker and Lewis (1973)) across heterogeneous groups (here between formal and informal settlement). We use a two-stage control function approach, which allows us to tackle the endogeneity of both family size and settlement choice before analysing the possible existence of a child QQ trade-off. Like recent studies in the QQ trade-off literature, specifically Mogstad and Wiswall (2016), we allow for non-linear effects of family size on child outcomes and also takes into account the existence of settlement-specific unobserved heterogeneity. After estimating the

[2] For more details, see Rossier et al. (2012)

control functions in the first stage, we implement a heteroskedastic bivariate probit model that allows for the endogeneity of settlement choice, and for different variances of unobserved heterogeneity in the formal and informal settlements.

In addition to the methodological contribution, this paper makes progress in studying the QQ trade-off in the African context. The study of QQ trade-offs remains important in general as many countries continue to invest heavily in policies that reduce population growth in the hope of increasing human capital investment. Arguably, the study of the QQ trade-off in Africa is becoming even more pertinent given the increased access to contraception and family planning, which is giving African parents greater control over family sizes (Bloom et al. (2003), Bougma and LeGrand (2013)). In general, the studies that have been done on the QQ trade-off in Africa, and elsewhere, have yielded mixed results of the effect of family size on child education outcomes. For example, little to no effects have been found in Israel (Angrist et al. (2010)) and Norway (Black et al. (2010)), positive effects have been found in urban Kenya (Gomes (1984)) and rural Botswana (Chernichovsky (1985)), and negative effects have been found in India (Rosenzweig and Wolpin (1980)) and China (Rosenzweig and Zhang (2009)). The theoretical model of a QQ trade-off can rationalize all of these findings, as the sign of the effect depends very much on the nature of the household utility function over child quality and family size. However, not every study on the QQ trade-off in Africa attempts to control for the endogeneity of family size. In addition, to the best of our knowledge, the few existing works on educational attainment in Burkina Faso that control for endogeneity (e.g. Bougma and LeGrand (2013)) have neglected the presence of unobserved heterogeneity among various sub-populations, and have imposed a constant marginal effect of family size on child schooling outcomes. In these regards, this paper contributes to the developing literature.

3. Data and empirical specification

3.1. Data

The data for this analysis was drawn from the Ouagadougou Health and Demographic Surveillance System (OHDSS). Launched in 2008, OHDSS is a research platform implemented in five neighbourhoods in the northern periphery of Ouagadougou. The two formal settlements studied are Kilwin and Tanghin, and the three informal settlements are Nanghin, Polesgo and Nioko 2. The OHDSS areas were chosen to target the most vulnerable populations of the city. The main objectives of the program are to understand the problems of the urban poor and to test programs that promote their well-being. The demographic surveillance consists of regularly updating data on vital events (births, deaths, unions) and migration events. This platform was constructed to put in contrast the two types of settlements in Ouagadougou, namely the formal and informal settlements. Since 2008, OHDSS has covered more than 80,000 individuals, which represents half of each type of settlement, and the data contains considerable information on individual and family characteristics. In particular, for each individual there is data on age, school attendance, literacy, labour-force participation, migrations, and marriages, as well as family characteristics such as the family's physical assets and living conditions. Fertility in this paper refers to the number of surviving children. The data comes from woman birth recode. Information, including the type of birth (twin or not) is provided by the woman at the moment of the survey. Data on education was collected in 2017 for all individuals aged 6 or older. Information collected was on past and current school attendance (during the 2016 - 2017 school year). This study focuses on two measures of educational attainment: the proportion of children who have ever been enrolled in school, and those who attended the post-primary level.

For our analysis several exclusion criteria were applied to the main data collected by the OHDSS. First, we restricted our sample to children aged at least 15 years old. This limitation avoided including primary school students/attendants in the post-primary analysis. Second, we limited individual's age to 30, to avoid including older cohorts that may have been exposed to widely different economic and institutional environments. Next, since we will use the presence of a twin as an instrument to resolve the endogeneity of family size, following the existing literature (i.e., Black et al. (2010) and Mogstad and Wiswall (2016)) we restrict the sample to children born before twin births. The exclusion criteria resulted in a final sample size of 1,094 first-born children from 15 to 30 years old. Table 1 presents the descriptive statistics of our main sample by settlement type.

[Table 1 here]

3.2. Empirical specification

3.2.1 Settlement-Specific Unobserved Heterogeneity, Endogeneity and Non-Monotonicity.

The goal is to construct a model that will allow us to estimate the differential effects of family size on educational attainment across the formal and informal settlements in Ouagadougou, where educational attainment is a binary outcome. We use two school outcomes. The first one is school enrolment that takes the value 1 if the child is enrolled in school and 0 if not. The second is the post-primary school attainment that takes the value 1 if individual has reached the post-primary level and 0 if not.

However, some modeling considerations should be taken into account such as 1) the possibility of differential residual variation across settlement types, 2) the possible endogeneity of both the family size and the family settlement choice, 3) the possible heterogeneous and non-monotonic relationship between family size and child outcomes.

To tackle some of these issues, several methodologies have been proposed in the literature, including those by Alvarez and Brehm (1995), Allison (1999), Williams (2009), and Long (2009). All these methods have been proposed for environments where all covariates are exogenous, while in our context two important variables are potentially endogenous. Moreover, unlike what is assumed in previous studies (see for instance Black et al. (2010)), when studying the QQ trade-off in the Norwegian context, Mogstad and Wiswall (2016) recently discovered that the family size may have a highly non-monotonic impact on child outcomes. Although our model will be non-linear by construction, we may want to consider a functional form for the outcome equation that does not impose monotonicity in the number of children. To deal with all of these concerns, we use a novel two-step control function approach. In the first step we construct two control functions: one for the number of children, and one for the number of children squared. In the second step, we implement a heteroskedastic bivariate probit model to model the endogeneity of settlement choice, and also for allowing settlement-specific unobserved heterogeneity. We will now explain in the following sections how we construct our model.

3.2.2 Identification and Econometric Specification : empirical Strategy for school enrolment and school attainment.

Consider the potential outcome model (POM) $S_i = S_{i1}D_i + S_{i0}(1 - D_i)$ Where $S_i \in \{0,1\}$ is an indicator function for child$_i$, that takes the value 1 if the child is observed to be enrolled in school, D_i indicates if the child is living in the formal (D_i= 1) or informal settlement (D_i= 0), and $S_{id} = 1\{S^*_{id} > 0\}$ is an indicator function of child i's school enrolment if he/she was randomly assigned to the settlement $D_i = d$, where S^*_{id} is the child's latent potential outcome. (Note that S_{i1} and S_{i0} are linked to S_{id}. Indeed, S_{i1} indicates that child$_i$, was randomly assigned to the formal settlement and S_{i0} indicates that child$_i$, was randomly assigned to the informal settlement). Since S_i is binary, the POM can be equivalently rewritten as:

$$S_i = 1\{(S^*_{i1} - S^*_{i0})D_i + S^*_{i0} > 0\} \quad (1)$$

We assume the following structure for the latent potential outcomes:

$$S^*_{id} = N_i\alpha^d_s + N_i^2\tau^d_s + X'_{is}\beta^d_s - e^d_{is} \quad (2)$$

where N_i represents the number of children in the family of child i, the vector X_{is} contains all observable child characteristics, and e^d_{is} is an error term whose interpretation will be discussed below.

After combining (1) with (2), we consider the following model :

$$S_i = 1\{N_i D_i \bar{\alpha}_s + N_i^2 D_i \bar{\tau}_s + X'_{is} D_i \bar{\beta}_s + N_i \alpha_s^0 + N_i^2 \tau_s^0 + X'_{is} \beta_s^0 > e_{is}(D_i)\} \quad (3)$$

$$D_i = 1\{X'_{il} \theta_l > e_{il}\} \quad (4)$$

$$N_i = X'_{i1} \theta_1 + \sigma_1 \epsilon_{i1} \quad (5)$$

$$N_1^2 = X'_{i2} \theta_2 + \sigma_2 \epsilon_{i2} \quad (6)$$

where we assume[3]

$\left(\frac{e_{is}^d,\ e_{il}, \epsilon_{i1}, \epsilon_{i2}}{\sigma_d} \middle| Z_i \right) \sim \mathcal{N}(0, \mathbb{W}_s)$ with Z_i a vector of exogenous covariates,

and where

$$\mathbb{W}_s = \begin{pmatrix} 1 & \rho_{sl} & \rho_{s1} & \rho_{s2} \\ \rho_{sl} & 1 & 0 & 0 \\ \rho_{s1} & 0 & 1 & \xi \\ \rho_{s2} & 0 & \xi & 1 \end{pmatrix}$$

and $\bar{\alpha}_s \equiv \alpha_s^1 - \alpha_s^0$, $\bar{\tau}_s \equiv \tau_s^1 - \tau_s^0$, $\bar{\beta}_s \equiv \beta_s^1 - \beta_s^0$ and $e_{is}(D_i) \equiv e_{is}^1 D_i + e_{is}^0(1 - D_i)$.

[3] This hypothesis refers to the assumption of normality of the joint distribution of the errors. These are the errors in the potential outcome, the settlement choice equation, the equation of the number of children, and the equation of the square of the number of children. It is important to postulate this assumption to ensure that we have minimum variance estimators.

Note that in $\mathbb{W}_s$, we consider that $Corr(e_{il}, e_{i1}|Z) = Corr(e_{il}, e_{i2}|Z) = 0$, but this is mainly for simplicity since our method does not relies on it. Indeed, if one consider only equation (4), (5), and (6), $Corr(e_{il}, e_{i1}|Z)$ *and* $Corr(e_{il}, e_{i2}|Z)$ can be consistently estimated using a parametric control function approach. In our case, when doing so the null hypothesis: $\widehat{Corr}\,(e_{il}, e_{i1}|Z) = \widehat{Corr}\,(e_{il}, e_{i2}|Z) = 0$ is not rejected even at 10%.

This model allows us to tackle this issue by allowing for heteroskedastic errors. Indeed, we follow Harvey (1976) and, more specifically, Alvarez and Brehm (1995), and model unobserved heterogeneity by adopting a multiplicative functional form for the variance Var(e_{is}^{d}) = $\sigma_d^2 = \exp(d\delta)$. In such a case Var($e_{is}^{0}$) = 1 and Var($e_{is}^{1}$) = $\exp(d\delta)$, where δ will be determined in estimation. Note that under our method it will be possible to test for the endogeneity of settlement choice by checking the significance of the parameter ρ_{sl} . To ensure clean identification, we consider the decade the family moved to Ouagadougou (if they moved) as an exclusion restriction. Twin births are used as instrument for Ni. Following Mogstad and Wiswall (2016), we construct instruments that account for the "partially missing instruments" problem inherent to twin births.

The model for post-primary school attainment is identical to the model given by equations (3)-(6) with the exception that equation (3) is replaced with:

$$\mathrm{Y}_i = 1\{N_i D_i \bar{\alpha}_{\mathrm{y}} + N_i^2 D_i \bar{\tau}_{\mathrm{y}} + X'_{i\mathrm{y}} D_i \bar{\beta}_{\mathrm{y}} + N_i \alpha_{\mathrm{y}}^0 + N_i^2 \tau_{\mathrm{y}}^0 + X'_{i\mathrm{y}} \beta_{\mathrm{y}}^0 > e_{i\mathrm{y}}(D_i)\} \quad (7)$$

Where $\mathrm{Y}_i \in \{0,1\}$ is an indicator for whether child i attended post-primary.

4. Estimation and results

4.1 Estimation

To estimate each model, we performed three steps. For the sake of simplicity, we drop the index i in the remaining discussion. Estimation of the model is identical whether we consider the school enrolment outcome (S) or the post-primary attainment outcome (Y). So, we will continue with school enrolment notation. We will also introduce the following notation[4]:

$$\zeta \equiv \sqrt{1-\frac{\rho_{s1}^2-2\xi\rho_{s1}\rho_{s2}+\rho_{s2}^2}{1-\xi^2}}, \quad W' \equiv [ND, N^2D, X_s'D, N, N^2, X_s'],$$

$$\theta \equiv [\bar{\alpha}_s, \bar{\tau}_s, \bar{\beta}_s, \alpha_s^0, \tau_s^0, \beta_s^0]', \quad \theta^* \equiv \frac{\theta}{\zeta}, \quad \rho_{sl}^* = \frac{\rho_{sl}}{\zeta}, \quad \gamma_1^* \equiv \frac{\rho_1-\xi\rho_2}{\zeta(1-\xi^2)},$$

$$\gamma_2^* \equiv \frac{\rho_2-\xi\rho_1}{\zeta(1-\xi^2)},$$

Furthermore, we shall use the notation $\Phi_2(.,.;\rho)$ to denote the bivariate standard normal cumulative distribution function with correlation parameter ρ, and $\Phi(.)$ as the univariate standard normal cumulative distribution function.

First Step: Control Function. From equations (5), (6) obtain the estimates

$(\hat{\theta}_{1,}\hat{\theta}_{2,}\hat{\sigma}_{1,}\hat{\sigma}_{2,})$ in the first-stage equations using ordinary least squares, and obtain the standardized residuals $\hat{\epsilon}_1 = (N - X_1'\hat{\theta}_1)/\hat{\sigma}_1$ and $\hat{\epsilon}_2 = (N^2 - X_2'\hat{\theta}_2)/\hat{\sigma}_2$. Also estimate $\hat{\xi} = \text{cov}(\hat{\epsilon}_1, \hat{\epsilon}_2)$.

[4] These notations were introduced to facilitate their inclusion in the definition of the log-likelihood function

heteroskedastic bivariate probit and obtain consistent estimates for $\theta^* \equiv [\overline{\alpha}_S^*, \overline{\tau}_S^*, \overline{\beta}_S^*, \alpha_S^{0*}, \tau_S^{0*}, \beta_S^{0*}]'$ by maximizing the following log-likelihood function:

$$\mathcal{L}(\overline{\theta}^*) = \sum_{i=1}^{n} \{s_i d_i \ln P_{11} + s_i(1-d_i)\ln P_{10} + (1-s_i)d_i \ln\{\Phi(x_l'\theta_l) - P_{11}\} + (1-s_i)(1-d_i)\ln\{1 - P_{10} - \Phi(x_l'\theta_l)\}\}$$

Where

$$P_{11} \equiv \Phi_2\left(\frac{W'\theta^*}{\exp(\delta)} - \gamma_1^*\hat{\epsilon}_1 - \gamma_2^*\hat{\epsilon}_2,\ x_l'\theta_l\ ;\ \rho_{yl}^*\right)$$

$$P_{10} \equiv \Phi(W'\theta^* - \gamma_1^*\hat{\epsilon}_1 - \gamma_2^*\hat{\epsilon}_2) - \Phi_2\left(W'\theta^* - \gamma_1^*\hat{\epsilon}_1 - \gamma_2^*\hat{\epsilon}_2, x_l'\theta_l\ ;\ \rho_{yl}^*\right)$$

Third Step: Recover Structural Parameters. Recover the structural parameters θ using the estimates obtained in the first two steps, and calculate confidence intervals for the structural parameters using a bias-corrected percentile bootstrap.

4.2 Results

Table 2 shows the results for the school enrolment outcome and school attainment. The first striking point is that the results show clear evidence of a different effect of family size on the first born child's school enrolment depending on whether the child lives in a formal or informal settlement. For school enrolment, the exogenous variation of family size due to the presence of twins in the family negatively affects the probability of child to be enroll in school in the informal settlement, unlike in the formal settlement where the effect is not significant. The effect N^2 is significant at the 5% level in the informal settlement using exogenous variation of the presence of twins in the family, but there is no significance at any conventional level in the formal settlement.

[Table 2 here]

The difference in the effect of family size between the settlements is found to be significant for school enrolment, as is seen in Table 3.

[Table 3 here]

Figure 1 provides information on the average treatment effect (ATE) of being in the formal versus the informal settlement on the first child's probability of being enrolled in primary school. In Figure 1(a) $P(Y_1 = 1|N = n)$ is always above $P(Y_0 = 1|N = n)$, which suggests a positive ATE at all margins. This shows that in terms of school enrolment there is a systematic advantage of living in the formal settlements, even after correcting for potential selection bias. Figure 1(a) also shows an inverse-U relationship between the probability the first child attends school and the number of children in the family, especially for the informal settlements. Figure 1(b) shows that the ATE does not seem to be significantly affected by gender, although it shows that the schooling probability tends to be slightly higher (but not significant) for boys in both settlements.

[Figure 1 here]

Interestingly, the conclusions from the schooling decision do not extend to the post-primary outcomes. Indeed, we find insignificant estimates of the effect of family size on whether the first child attains a post-primary level of education for both the formal and informal settlements, and no significant differences between the settlements.

Since behaviour towards schooling can be different across genders, we also estimate the model on male and female-only sub-samples. Table 4 displays the results. For the post-primary outcome we find a significant difference in the effects of family size between the two settlements for male children, but no significant differences for female children. Similar to the schooling outcome, any QQ trade-offs seems to be local to the informal settlements: the formal settlement is found to have insignificant estimates of the effect of family size on post-primary attainment for both males and females across all instruments. For the male-only sample, we find a significant inverse-U relationship between the probability of post-primary attainment and family size in the informal settlement. However, in the female-only sample, the probability of post-primary attainment is found to be decreasing in family size. This result is consistent with the conclusions of Lachaud et al. (2014) who use a similar sample. They find first-born females in Ouagadougou from smaller families are less likely to attend post-primary, whereas first-born males from smaller families are more likely to attend. However, Lachaud et al. (2014) do not control for the potential endogeneity of family size, and do not consider settlement-

[5] As mentioned in the section at the end of the section 3.2.2 the model for post-primary school attainment is identical to the model given by equations (3)-(6) for school enrolment with the exception that equation (3) is replaced with: $Y_i = 1\left\{N_i D_i \bar{\alpha}_y + N_i^2 D_i \bar{\tau}_y + X'_{iy} D_i \bar{\beta}_y + N_i \alpha_y^0 + N_i^2 \tau_y^0 + X'_{iy} \beta_y^0 > e_{iy}(D_i)\right\}$

specific differences. Our results show that conclusions similar to those of Lachaud et al. (2014) hold after controlling for the endogeneity of family size, but are only significant in the informal settlements.

[Table 4 here]

Taken together, the results on the QQ trade-off with respect to both the school enrolment and post-primary attainment outcomes seem to be in line with the result of Li et al. (2007), who find greater evidence of family size effects on child education in rural China versus non-rural China while also using twin instruments. The results provide some evidence that family size has stronger effects on child education outcomes in regions characterized by low-income, low-quality public education, and low-educated parents. However, it is worth noting that unlike us, Li et al. (2007) rely on a specification that is linear in the number of children, so that they implicitly assume a constant marginal effect of family size on child education outcomes.

When relaxing this linear specification in our context, our findings of a significant non-linear effect of family size on education outcomes in the informal settlements (particularly for the school enrolment outcome) are consistent with the findings of Mogstad and Wiswall (2016) in the Norwegian context. As discussed in Mogstad and Wiswall (2016), the inverse U-shape of the probability curve in figure 1 suggests that family size does not necessarily have a monotonic, negative impact on child school attendance at all margins. Indeed, in our context there is a positive impact of family size for families with 4 or fewer children, and a clear negative effect for families with 5 or more children. In other words, 4 children seems to be a critical threshold beyond which there are some adverse effects of having additional children on the existing child outcomes. Although this differs substantially from the results of Mogstad and Wiswall (2016) in the Norwegian context, which show that this threshold is closer to 2 children, this difference is consistent with the fact that average family sizes are much larger in west-Africa.

Mogstad and Wiswall (2016) argue that this U-shape pattern could be interpreted as substitution effects between child quantity and quality in large families (more than 4 children in our context), and complementary effects between quantity and quality in small families (less than 4 children). There are a few possible ways to rationalize these findings. We know that within the informal settlement there are a higher proportion of non-educated parents who usually work in informal businesses where small children can help and participate. To be specific, in our sample 74% of fathers in the informal sector have jobs in which the child can participate versus 66% in the formal sector, with the difference significant at the 1% level. In addition, 95% of mothers in the informal sector have jobs in which the child can participate versus 88% in the formal sector, with the difference also significant at the 1% level. Within the informal settlement, 82% of families use wood as a main source of energy and only 3% have water access at home. Under such circumstances the presence of an additional child may increase the labor force at home and weaken the burden on the first child. Parents may therefore be more inclined to allow the first child to enroll in school. However, as the family size becomes large enough (i.e. beyond 4 children), the pressure on family resources may begin to counteract any such effect.

Another possible explanation follows that of Qian (2009), who also finds that the presence of an additional child has a positive impact on the school enrolment of the first child in the context of China. Qian (2009) rationalizes her result by suggesting that there may exist economies of scale in the costs of education for the first few children; for example, in the cost of school supplies. She provides support for this claim by showing that the effect of additional children on the schooling enrolment of the first child is especially large when the siblings are of the same sex (which may serve to reduce the cost compared to the case when the siblings are of opposite sex). Beyond the first few children this effect may deteriorate, especially if all children are attending school simultaneously (and thus compete for family resources).

However, these interpretations may only be valid for the informal settlements. In the formal settlements, although our coefficients on N and N^2 are found to be insignificant they suggest very different behaviour from the informal settlement estimates. As can be seen in figure 1 we do not observe much evidence of an inverse U-shape, but instead we observe a small and negative causal effect at all margins. Taken together these results are indicative of a different type of quantity-quality trade-off between the families in the formal and informal settlements.

To summarize, our results suggest (i) QQ trade-offs are made, but mostly in the informal settlements, (ii) statistically significant differences in QQ behaviour exist between the formal and informal settlements, and (iii) the differences in quantity-quality trade-offs may depend on both the education outcome considered as well as the gender of the child.

Motivated by the context of Ouagadougou, Burkina Faso, we develop a method that can be used to study disparities in QQ trade-offs accross heterogeneous groups. We apply the method to data from Burkina Faso to study these disparities between the formal and informal settlements in Ouagadougou. Despite the efforts taken to control for endogeneity of family size, settlement choice, and settlement-specific variance of unobservables, we do not find conclusive evidence that these effects were relevant in our context. However, we do find some evidence of a QQ trade-off in the informal sector that is significantly different from that in the formal settlement. Using a model that does not impose monotonicity in the effect of family size on child education outcomes, we find that the QQ trade-off in the informal sector follows the inverse-U shape found in Mogstad and Wiswall (2016). The model we have presented to analyze the QQ trade-off in the context of Ouagadougou could be of help to researchers trying to understand different perceptions of education across heterogeneous groups, especially in the context of developing countries. We have tried to show in this paper that, when analyzing concepts like the QQ trade-off that are important in development economics, it is important to account for heterogeneity that may exists across sub-populations within a given sample. While we interpret our results with caution, in order to reduce settlement disparities we recommend prioritizing actions to improve school quality in the urban informal settlements. Our results also suggest that efforts to keep children in school should not be directed only towards rural areas. In addition to reducing schooling costs in some urban areas, particularly informal areas, special emphasis should be put on raising awareness about the benefits of education for the welfare of children and their families.

in the informal settlement. The causes can be seen from both the school supply and demand side. Indeed, people in the informal settlement are poor people with little means to educate their children. Moreover, because of their informal nature, this type of settlements lack public school infrastructure, which accentuates the difficulties of schooling. So, restructure the informal settlements in the city of Ouagadougou by providing them with all basic social services, including schools and public health services is a necessity to improve schooling in these settlements.

Our study was conducted in the five settlements of the Ouagadougou Health and Demographic Surveillance System. These settlements were selected in a non-random way to conduct interventions on poor populations in order to improve their living conditions. It would therefore be desirable, in order to confirm our conclusions, to conduct the same study on a random sample of formal and informal settlements of the city of Ouagadougou.

In addition, to better understand the results of our study, particularly the non-existence of endogeneity in the number of children in the explanation of children's schooling, it would be desirable to supplement this study with a qualitative study. Indeed, the absence of endogeneity of the number of children suggests that parents generally do not take into account children's schooling when choosing the number of their children. A qualitative study could better inform on the possible reasons.

Tables and figures to be inserted

Table 1. Descriptive statistics (15-30 year old group)

	Formal settlement		Informal settlement		
Variables	Mean	SD	Mean	SD	Mean differe
Age of Child	23.11	4.4	21.87	4.06	***
Child is a Girl	0.5	0.5	0.53	0.5	NS
Child is a Muslim	0.6	0.49	0.51	0.5	***
Child belongs to Mossi ethnic group	0.89	0.31	0.93	0.26	*
Enrolled in school at least once	0.95	0.21	0.86	0.35	***
Child reach 7 during f	0.19	0.39	0.25	0.43	**
Child reached post-primary schooling	0.7	0.46	0.49	0.5	***
Number of children in the family	4.66	1.59	4.91	1.43	**
Presence of twins in the family	0.11	0.31	0.08	0.28	NS
Child's mother's age	44.04	4.36	42.62	3.9	***
Child's mother's husband's age	53.05	8.02	50.8	8	***
Mother has at least primary school	0.44	0.5	0.26	0.44	***
Husband has at least primary school	0.51	0.5	0.3	0.46	***
Poor	0.18	0.38	0.46	0.5	***
Middle	0.13	0.33	0.21	0.41	***
Rich	0.7	0.46	0.33	0.47	***
Moved to Ouaga in 1960s	0.01	0.1	0.01	0.08	NS
Moved to Ouaga in 1970s	0.15	0.36	0.11	0.32	*
Moved to Ouaga in 1980s	0.38	0.49	0.33	0.47	NS
Moved to Ouaga in 1990s	0.16	0.37	0.26	0.44	***
Moved to Ouaga in 2000s	0	0.05	0	0.06	NS
Moved to Ouaga in 2010s	0	0	0	0	NS
Observations	816		278		

Table 2. Estimates of Structural Parameters in the Outcome Equation for Primary and Post-Primary Outcomes

	Primary	**Post -Primary**
ρ_{s1}	-0.02	0.04*
ρ_{s2}	-0.03	0.05*
ρ_{sl}	-0.08	-0.05
δ	-0.04	0.02
Informal settlement		
N	-0.12**	-0.08
N^2	-0.01**	0.01
Age	-0.01	-0.01*
Mother Age	0.01*	0.00
Father Age	0.00	0.00
Girl	-0.01	-0.04***
Muslim	-0.13***	-0.02
Mother Schooling	0.05**	0.06***
Father Schooling	0.00	0.01
Poor	-0.02	0.31
Middle	0.00	0.32
Rich	-0.01	0.35*
Formal settlement		
N	0.02	-0.09
N^2	0.00	0.03
Age	0.00	0.00
Mother Age	0.01***	0.00
Father Age	0.00	0.00
Girl	-0.03	-0.01
Muslim	-0.06**	-0.04***
Mother Schooling	0.07***	0.04***
Father Schooling	0.10***	0.04***
Poor	-0.03	0.60**
Middle	0.06	0.58**
Rich	0.06	0.67**

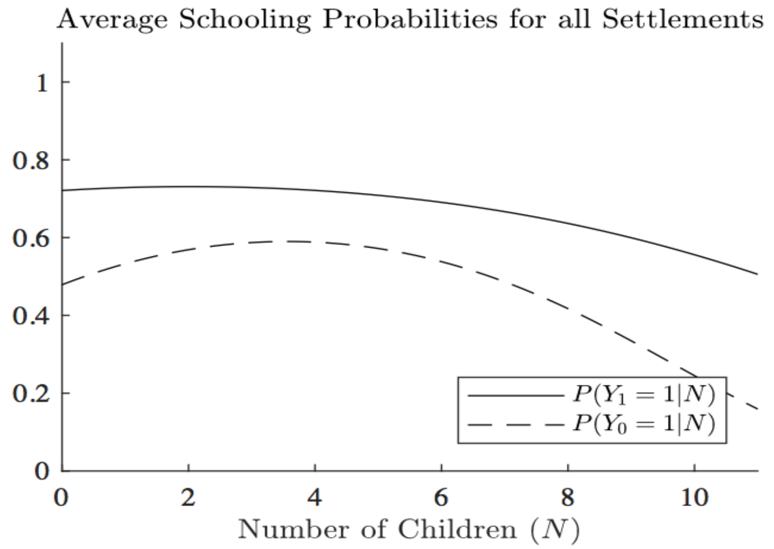
Table 3 : Difference of Structural Parameters in the Outcome Equation: Formal Settlement Estimates - Informal Settlement Estimates

	Primary	**Post -Primary**
N	0.09**	-0.01
N^2	0.01**	0.00
Age	0.01*	0.01
Mother Age	-0.00	0.00
Father Age	0.00	0.00
Girl	0.01	0.03*
Muslim	0.06**	-0.01
Mother Schooling	0.02	-0.02
Father Schooling	0.09**	0.02
Poor	-0.01	0.29**
Middle	0.06	0.26**
Rich	-0.07	0.32**

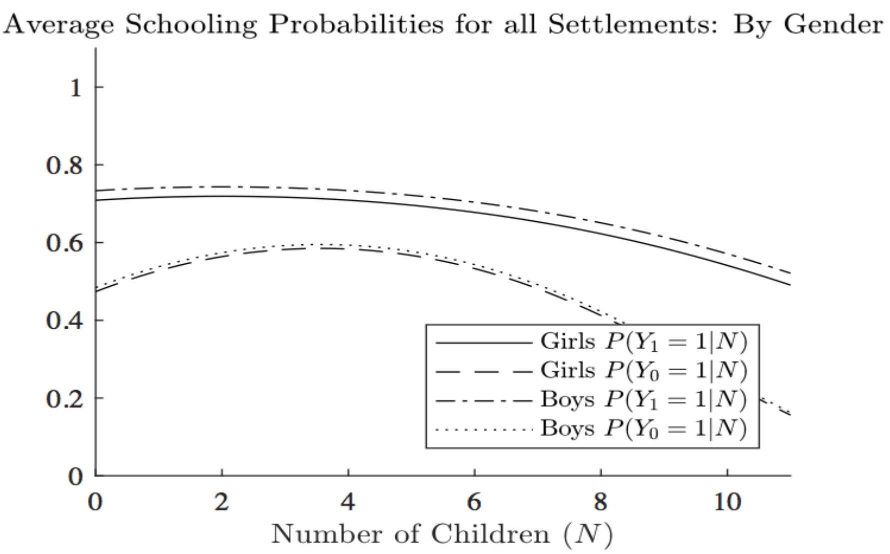
Table 4 : Male/Female Difference of Structural Parameters in the Outcome Equation: Formal Settlement Estimates - Informal Settlement Estimates

	Male children	**Female children**
Schooling		
N	0.32	-0.07**
N^2	0.06***	0.00
Age	-0.05	0.02**
Mother Age	0.08***	-0.01**
Father Age	-0.03**	0.00
Muslim	0.07	0.06**
Mother Schooling	0.22	0.06*
Father Schooling	-0.04	0.04*
Poor	-0.13	-0.09
Middle	-0.11	-0.01
Rich	0.33*	-0.14
Post-primary		
N	-0.07*	0.02
N^2	0.01**	0.00
Age	-0.01	0.03**
Mother Age	0.00	-0.01**
Father Age	0.00	0.00**
Muslim	0.01	-0.06**
Mother Schooling	0.00	0.05
Father Schooling	-0.01	0.03
Poor	0.45**	0.46**
Middle	0.04**	0.10*
Rich	0.08**	-0.13**

Figure 1. Predicted Probabilities: $P(Y_1 = 1|N = n)$ and $P(Y_0 = 1|N = n)$



(a)



(b)

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Appendix : Creating Instruments from the Presence of Twins in the Family

To address the possible endogeneity of N_i and N_1^2, we will take advantage of the presence of twins in the family to determine the causal effect of family size on children's school enrolment and post-primary school attainment.

We use the indicator variable $twin_{i,k+1}$ that is equal to 1 if there is a twin at the $(k + 1)^{th}$ birth in individual i's family as a instrument. Since we restrict our sample to the first-born children before the twin birth (i.e., first-born children who are not twins), using this instrument will allow us to estimate the average treatment effect for the compliers at the k^{th} margin (i.e., the local average treatment effect, or LATE(k)). However, the instrument $twin_{i,k+1}$ is not defined for families with less than k+1 children. This is an example of the problem of « partially missing instruments », which has been discussed in Angrist et al. (2010), Mogstad and Wiswall (2012), and Mogstad and Wiswall (2016). In response to this problem, Mogstad and Wiswall (2016) propose a method to modify the $twin_{i,k+1}$ instrument in order to construct an instrument defined on the entire sample. We follow their lead, and construct the instruments for N_i as follows:

$$twin^*_{i,k+1} = \begin{cases} 0 & \text{if } N_i < k+1, \\ twin_{i,k+1} - \hat{\mathbb{E}}[twin_{i,k+1} | x^{twin}_{i,k+1}, N_i \geq k+1] & \text{if } N_i \geq k+1, \end{cases}$$

Where $x^{twin}_{i,k+1}$ is vector of variables that may predict twinning at the $(k + 1)^{th}$ birth. In practice we use the same variables as predictors for each k. Finally, since we need two instruments for our two endogenous variables N_i and N_i^2, we consider $\left(twin^*_{i,k+1}\right)^2$ as the second instrument.