Income Shocks and Gender Gaps in Education: Evidence from Uganda*

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Abstract

This paper uses exogenous variation in rainfall across districts in Uganda to estimate the causal effects of household income shocks on children's enrollment and cognitive skills conditional on gender. I find negative income shocks to have large negative and highly significant effects on female enrollment in primary schools and the effect grows stronger for older girls. The effect on boys' enrollment is smaller and only marginally significant. Moreover, I find that a negative income shock has an adverse effect on test scores in general and test scores of female students in particular. The results imply that households respond to income shocks by varying the quantity and quality of girls' education while boys are to a large extent sheltered – a finding consistent with a model where parents' values of child labor differ across sexes.

Keywords: Rainfall, education, test scores, gender

JEL-classification: O12, I21, D13

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1 Introduction

The question of how changes in households' economic conditions differentially affect the treatment of boys and girls in developing countries has long been a concern among development economists and policymakers. Understanding households' decisions regarding their children's education and food consumption conditional on gender in a risky environment is important in order to design sustainable policies to promote gender equality. The importance of this issue has been reemphasized in recent years since promoting gender equality has been identified as one of the most important goals of the donor community in the next decade, e.g. the Millennium Development Goal.

Starting with Becker (1981), economists have long argued that households' differential treatment of children conditional on gender can be explained by the underlying economic conditions. For example, Rosenzweig and Schultz (1982) show that households selectively allocate resources to children in response to variations in sex differences in their expected earnings opportunities as adults. Foster (1995) finds that a child's well-being varies with fluctuations in income and prices and that the well-being of girls is more sensitive to these fluctuations than that of boys. Similarly, Behrman (1988) has shown that girls' nutrition suffers more than that of boys in the lean, as opposed to the peak, agricultural season. Differential treatment of boys and girls with regard to intra-household food allocations and its long-term consequence on female infanticide and gender imbalance have been documented as an evident phenomenon in Asia by Rose (1999), Qian (2005) and others.

One of the more striking (and visible) examples of differential treatment of boys and girls within households in developing countries is the prevalent gender bias in education. Girls tend to receive less schooling than boys in general, particularly so in rural areas, low income countries and South Asia (Behrman and Knowles, 1999; Alderman et al., 1996). The possible causes of this gender gap in schooling have been subject to less study and similarly, the nature of the relationship between changes in households' economic conditions and differential treatment in children's education is anything but settled.

The main empirical challenge in establishing the link between households' economic conditions and differential investments in boys' and girls' schooling is that economic conditions and intra-household allocations are endogenous to schooling and family structure. The estimated effect of household income on children's developmental outcomes might be spurious, because parental income and outcomes for children may both be driven by an unmeasured factor such as health. Randomized experiments constitute one solution to this omitted-variables problem. In the absence of evidence from such experiments, however, it is necessary to rely on exogenous natural variations in combination with statistical modeling strategies.

The principal contribution of this paper is to develop and implement a strategy capturing the causal effect of changes in households' economic conditions on the differential investment in children's primary education. In particular, I exploit the exogenous variation in district income in Uganda over time caused by rainfall shocks to study the causal effects of household income shocks on boys' and girls' primary education attainment and achievements. Uganda is an agricultural country where more than 90% of the work force are employed in the mainly rainfed agricultural sector. Therefore, rainfall shocks are plausible proxies for income shocks to households.[1] In addition to the methodological contribution, the paper is a first attempt at explaining differential treatment in education in an African setting.[2]

When a household experiences a negative income shock, there are two potential effects that could differentially affect investment in boys' and girls' schooling. First, a transitory shock will force the household to reduce current consumption. If the reduction in food consumption and/or school expenditures has different effects on boys and girls, then girls' ability to perform in school might be affected. Second, in periods of transitory shocks, households (and specifically women) are forced to find alternative income generating activities and food and therefore, the demand for children's participation in home production increases. If the domestic work load is differentially allocated across boys and girls, this will affect both the quantity and the quality of the education of girls relative to that of boys. In the paper, I develop a simple human capital model where parents view children's education as a form of investment to illustrate these effects. I derive the equilibrium level of schooling (enrollment) and the cognitive skills of boys and girls and evaluate how enrollment and cognitive skills vary with income.

The empirical findings are broadly consistent with the model. I find a negative income shock to households to have an immediate and negative effect on female enrollment in primary schools and the effect grows stronger for older girls. A decrease in rainfall of one standard

[1] Other studies that have used rainfall as an instrument for income in developing countries are i.e. Miguel et al., 2004; Paxson, 1992; Rose, 1999 and Miguel 2005.

[2] Previous studies on differential treatment in education have been conducted with data from Asia (Alderman et. al., 1996; Kingdon, 2002, Behrman and Knowles, 1999; Qian, 2005).

deviation from its historical mean results in 18 percentage points fewer female students in grade 7, which corresponds to a decrease of 0.21 standard deviations in female enrollment. Conversely, a negative income shock of one standard deviation decreases male enrollment in Primary 7 by 0.10 standard deviations, but the effect is insignificant at standard levels of significance. Moreover, I find a negative income shock to have an adverse effect on test scores in general and test scores of female students in particular. The results imply that households respond to income shocks by varying the quantity and quality of girls' education, while boys are to a large extent sheltered. Moreover, the evidence suggests that the driving mechanism is the differential benefit from child labor (in home production). Specifically, while there is suggestive evidence that households in poor countries respond to transitory income shocks by increasing child labor, I find that it is primarily girls' labor that is used as a buffer.

In this paper, I also exploit a natural policy experiment – the removal of school fees in primary education – to estimate the effects of a reduction in the (formal) cost of schooling on the relative quantity and quality of the education of boys versus that of girls. While suggestive, the evidence suggests that the removal of school fees has a large and positive effect on the enrollment of both boys and girls, although it is stronger for girls. Moreover, after the abolishment of user fees in primary schools, a negative income shock has an even larger negative effect on female enrollment, while boys still remain unaffected.

The remainder of the paper is organized as follows. Section 2 describes the literature and the gender situation in Uganda. Section 3 presents the conceptual framework and Section 4 describes the data. The identification strategy is discussed in Section 5. Section 6 presents the results for enrollment and test scores and Section 7 describes the robustness analysis. Conditional findings are presented in Section 8 and Section 9 concludes.

2 Background

2.1 Previous Works

The literature studying the relationship between household economic conditions and investment in children starts with Becker (1981). He argues that sex preference reflects underlying economic conditions and show theoretically that increased income leads to an increase in the relative demand of girls. This is consistent with Rose's (1999) study in India, which examines the relationship between consumption smoothing and excess female mortality. She finds favorable rainfall shocks in childhood to increase the ratio of the probability that a girl survives to the probability that a boy survives.

Another strand of the literature has studied how relative female income affects investment in children. For India, Rosenzweig and Schultz (1982) show that female children receive a larger share of family resources and have a greater propensity to survive relative to male children in communities where females are considered to be more economically productive as adults relative to males. For China, Qian (2005) estimates the effects of total income, relative female and relative male income on sex ratios of surviving children and educational attainment. She finds that increasing total income has no effect on sex ratios, increasing female income increases the survival rates for girls and the educational attainment for all children whereas increasing male income decreases the survival rates and the educational attainment for girls but has no effect on boys. Duflo (2000) exploits the Old Age Pension program in South Africa and finds improvement in the health and nutrition status of children, especially for girls. She finds the effect to be driven by pensions received by women.

Previous work has also examined how changes in households' economic conditions affect children's developmental outcomes, i.e. in terms of schooling and health. Foster (1995) finds variations in child weight after the severe floods in 1988 in rural Bangladesh and he indicates that a child's well-being varies with fluctuations in income and prices. In India, Jacoby and Skoufias (1997) show that unanticipated income shocks have a significant effect on children's school attendance and that school attendance appears to play an important role in the self-insurance strategy of poor households. For Côte d'Ivoire, Jensen (2000) uses data for two years and investigates whether volatile income in an environment of incomplete insurance or capital markets leads to lost opportunities for investment in children and the development of human capital. He finds that school enrollment decreased, less children sought medical health care and malnutrition increased in regions that experienced a rainfall shock. For Pakistan, Alderman et al. (2001) determine the child health stock by using price shocks when the children were of pre-schoolage and they find strong effects of child health on school enrollment. Beegle et. al (2003) use data from Tanzania and find that households respond to transitory income shocks by increasing child labor and the extent to which child labor is used as a buffer is lower when households have access to credit. Although previous studies have found investments in children to be correlated with household income, few previous studies have assessed the relationship between household economic conditions and differential investment in boys' and girls' schooling.

2.2 Gender in Uganda

> *In many traditional families, the man is presented with all the food, and only after he has taken as much as he wants will the other members of the household be served. Older boys eat second, some times sharing their father's dish. Women, girls and small children eat last. (World Bank, 1993, p.10)*

In Uganda, there are pervasive gender inequalities in access to education, employment, credit and land. Women are responsible for producing 80 percent of the food and provide about 70 percent of the total agricultural labor force, but lack control over land, the crops they produce, livestock and other productive resources. Though women bear the brunt of providing labor for most agricultural operations, their land ownership rights are mainly limited to usufruct rights. Women only own 7 percent of the registered land in Uganda and have access to agricultural land only through their husbands or male relatives; when widowed or divorced they lose this access.[3] The traditionally determined insecurity in access to and control over land and resources makes it difficult, if not impossible, for women to take decisions regarding their use or reap benefits and income from the sale of produce.

Poor households use their children's labor and girls often have to assist in the care of younger siblings and domestic chores. A great share of the household tasks are performed by women/girls, i.e. child rearing, food preparation, fetching water, collecting firewood, washing clothes and taking care of the sick and old.[4] Although biological conditions might suggest males to be stronger and more able to perform certain household tasks, there is a strong perception that domestic chores are a female responsibility and that women/girls are more productive in performing these tasks as compared to males. Moreover, girls' productivity in home-production is increasing in age since older girls are able to take on greater responsibility and perform more tasks than girls at a young age. Accordingly, the household's use of girls in home-production becomes more pronounced the older are the girls.

[3] African Development Fund (2005).
[4] A World Bank Country Study, 1993.

Lacking pension programs and saving options, families in Uganda rely on their children as a source of income at old age. When marrying, a woman goes to live with her husband in his home and hence, her contribution as an adult benefits the husband's family. Sons, on the other hand, marry and remain in the family and the boy's contribution as an adult benefits his family. Consequently, parents rely on their sons to look after them in old age.

Although women in Uganda are responsible for most of the agricultural production and domestic chores, they have little to no decision-making power within the household and it is the male head of household (i.e. husband, father or brother) who determines the decisions.[5] In Uganda, communities have strong cultural gender based biases towards boys. Moreover, the perception that women are less economically valuable is intensified by a legal system and institutional constraints limiting women's rights to own property and their access to productive resources. The cultural, social, and legal institutions make the male head of household biased towards boys, which is strongly reflected in the household's investment in its children.

When modeling intra-household decisions, the bargaining model is preferred, since it accommodates the conflict of preferences and asymmetric power relations within the household and further, in the bargaining model, women's relative well-being depends on the relative bargaining power of the spouses. However, in an Ugandan setting (which is not unlike many countries in Sub-Saharan Africa) where cultural, social, and legal institutions basically give all bargaining power to the man, one could simply look at the outcomes from a male head of household maximizing problem when modeling the household's decisions.

3 Conceptual Framework

This section presents a simple human capital model with intra-household choices on the quality and quantity of children's education. I use this framework to show how children's abilities in domestic work, learning efficiency, expected returns to education as well as parental income affect the household's investment in children's primary education.

[5] African Development Fund (2005).

3.1 Basics

Assume that parents make decisions for their children. There is a continuum of families that could potentially send their children to school. To simplify, assume that each family i has two children – a boy (denoted with subscript b) and a girl (denoted with subscript g). There are two periods. In period 1, the child works at home, goes to school, or both. In the second period, the child is an adult and works for a wage. In period 1, the parents derive direct benefit from the child's domestic work, while in period 2 the parents benefit from transfers from their child (now an adult).

The parents' utility is

$$U_i = u(c_1^i) + \delta c_2^i \ , \tag{1}$$

where c_t^i is ith parents' consumption in period t, δ is a discount factor and u is a function, with $u' > 0$, $u'' < 0$, and $u''' \geq 0$.

Cognitive skills, a, are acquired according to

$$a_s^i = \alpha_s^i s_s^i \ , \tag{2}$$

where α_s^i is the learning efficiency of a child of sex s in family i (which depends on many factors, such as innate ability, child motivation, etc.). For simplicity, I assume equal learning efficiency between boys and girls in family i, $\alpha_b^i = \alpha_g^i = \alpha^i$, and that α^i is distributed according to $f(\alpha^i)$ over the unit interval. s_s^i is the fraction of time in period 1 spent in school by a child from family i of sex s, where $s_s^i \in [0,1]$. Alternatively, s could be interpreted as the division of resources (food) within the family, i.e. between children of different sexes.

Parents' consumption in period 1 is given by

$$c_1^i = y_1 - pe_b^i - pe_g^i + \eta_b(1 - s_b^i) + \eta_g(1 - s_g^i), \tag{3}$$

where y_1 is parental income (exogenous) in period 1, p is the price of schooling for one child, e_s^i is a dummy variable taking the value of 1 if family i sends the child of sex s to school, and $\eta_s(1 - s_s^i)$ is the income generated from home production by that child in period 1.

The family's consumption in period 2 is given by

$$c_2^i = y_2 + \gamma_b y_b^{ai} + \gamma_g y_g^{ai} \ , \tag{4}$$

where y_2 is parental income (exogenous) in period 2, y_s^{ai} is the child's income when working as an adult in period 2 and $\gamma_s y_s^{ai}$ is the share of the child's income (as an adult) transferred to his/her parents.

Equation (5) completes the model, relating child cognitive skills to the child's income as an adult

$$y_s^{ai} = \omega_s a_s^i, \tag{5}$$

where ω_s is the return to education of a child of sex s. In this simple model, parents are liquidity constrained and cannot borrow or save. The only way of shifting income between periods is to alter the investment in children's education.[6]

Based on the discussion in section 2.2, in an African setting (or at least in a Ugandan setting), it is reasonable to assume that girls' labor at home is viewed as more valuable than that of boys. Specifically, cultural norms and perceptions about domestic chores suggest that girls are regarded as being more productive in taking care of siblings and other home production (cleaning, cooking etc.). Normalizing η_b, I thus assume $\eta_g > \eta_b \equiv 1$. It is also reasonable to assume that households perceive that a boy's contribution to the household as an adult will be larger than a girl's transfer, since the girl will marry and leave the natal household, implying that $\gamma_b > \gamma_g$. Finally, while the limited evidence on the social returns to education suggests that $\omega_g \geq \omega_b$, it is plausible to assume that the expected private return (viewed by the parents or the male head of household) is $\omega_b > \omega_g$.[7]

To simplify the notation, without loss of generality, I assume that $p = 1$ and normalize θ_b to 1, where $\theta_s \equiv \delta\gamma_s\omega_s$. Given the above assumptions, this implies that $\theta_g < \theta_b \equiv 1$.

3.1.1 Private optimum and equilibrium outcomes

The optimal choice of children's education can be found by maximizing the parents' expected utility, (1), subject to the budget constraints (3)-(4). The first-order condition (for an interior solution) of household i for a child of sex s is

$$-u'(c_1)\eta_s + \alpha_s^i \theta_s^i \leq 0 \quad \text{for } s_s \in [0, 1], \tag{6}$$

[6] Introducing savings and borrowing would reduce parents' incentives to invest in education but would not eliminate them. Specifically, if all investments are assumed to be risky, parents will diversify their investments along several different alternatives, including children's education (Glewwe, 2002).

[7] See Summers (1994) and the discussion in section 6.

Thus, for a given ability, α^i, parents will choose to invest in education up to the point where the marginal cost of more schooling, taking the form of reduced time for domestic production, is equal to the marginal gain, taking the form of increased transfer from a more educated and hence higher paid child. The properties from this simple model are summarized below.

Proposition 1 *a) It is always optimal for parents to invest in more (or at the minimum as much) education of the boy as compared to the girl, $s_b \geq s_g$; b) A girl will attend school iff the boy is sent to school full-time; c) a reduction in the boy's education is only optimal iff the girl works full-time in domestic work; d) If both $s_b > 0$ and $s_g > 0$, a reduction in parental income, y_1, will on the margin only reduce investment in the girl's education; e) a reduction in parental income, y_1, primarily affects the girl's cognitive skills, a_g.*

Proof. See the Appendix.

These results are intuitive. From the first-order condition it follows that for a given α, the marginal cost of schooling is lower and the marginal return is higher for boys as compared to girls. Thus, parents have incentives to increase s_b as far as possible, i.e. $s_b = 1$, before investing in the girl's education. For the same reasons, a change in parental income, y, will affect s_g as long as $s_g > 0$ and thus, it will on the margin primarily affect the quantity and quality of girls' education.

Given the assumption that parents differ in the innate ability of their children, α^i, we can derive the equilibrium number of boys and girls in school and their average cognitive skills ($\alpha^i s^i$) for a given (average) income y_1. Formally, the shares of boys (BiS) and girls (GiS) in school are

$$BiS = 1 - F(\alpha_1(y)) \tag{7}$$

and

$$GiS = 1 - F(\alpha_3(y)), \tag{8}$$

where $\alpha_1 = u'(y + \eta_g)$ and $\alpha_3 = u'(y + \eta_g - 2)\frac{\eta_g}{\theta_g}$ are the threshold values of α for boys and girls, for a given y, and when $s_s = 0$. Note that $\alpha_1 < \alpha_3$.

Proposition 2 *If $f(\alpha)$ is symmetric and unimodal and at least half the population of girls is enrolled in school, then an income shock will have a larger effect on the enrollment of girls than on that of boys.*

Proof. Differentiating BIS and GIS with respect to y gives:

$$\frac{dBiS}{dy} = -f(\alpha_1(y))\alpha_1'(y) < \frac{dGiS}{dy} = -f(\alpha_3(y))\alpha_3'(y).$$

If $f(\alpha)$ is symmetric and unimodal, then $f(\alpha)$ is maximized at $\alpha = \frac{1}{2}$ and $f'(\alpha) > 0$ for $\alpha < \frac{1}{2}$. Since $\alpha_1 < \alpha_3$, it follows that $f(\alpha_3(y)) > f(\alpha_1(y))$ for all $\alpha_3 \leq \frac{1}{2}$. Moreover, $-\alpha_1'(y) = -u''(y + \eta_g) < -u''(y + \eta_g - 2)\frac{\eta_g}{\theta_g} = -\alpha_3'(y)$ since $u''' > 0$, $\eta_g > 1$ and $\theta_g < 1$.[8]

Intuitively, if the marginal cost is higher and the marginal return is lower for girls' schooling, parents will, if possible, adjust the quantity and quality of girls' education in response to an income shock. These individual effects will also guide the aggregate outcome, provided that most households send both their children to school.[9]

Figure 1 illustrates the property of propositions 1 and 2 for the case where α^i is distributed according to a beta distribution over the interval $[0, 1]$.[10]

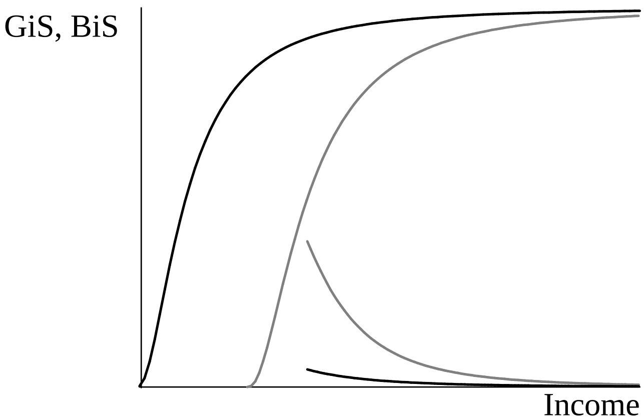

Figure 1: Enrollment of girls and boys conditional on income and corresponding derivatives.

[8]Proposition 2 states the sufficient conditions for $dBiS/dy < dGiS/dy$. Assuming a specific distribution, it can be shown that the results typically hold more generally. For example, if $f(\alpha)$ is uniform, then $dBiS/dy < dGiS/dy$ independent of the population of girls enrolled in school, provided that some girls are indeed in schools. If $f(\alpha)$ is a beta distribution, the results will hold for $\alpha_3 > \frac{1}{2}$ (i.e. when less than half the population of girls is in school) provided that η_g is large.

[9]The share of girls enrolled in primary school in Uganda during the period 1992-2002 was higher than 50% (World Bank, 2002).

[10]In figure 2, I assume $u(c) = \ln(c)$, η_g =1.1, and θ_g =0.9.

The two concave curves show the enrollment of girls (gray line) and boys and the convex lines in the lower part of the figure depict the derivatives of the enrollment of girls (gray line) and boys with respect to y.

I can also do comparative statics on changes in the formal cost of schooling, p, as well as study whether the effect of income shocks on boys' and girls' enrollment is different in poor and wealthy districts. The results are rather complicated and discussed in Section 8.

The average ability of boys enrolled in school is

$$a_b = BiS^*(y)\int_{\alpha_2}^{1}\alpha f\left(\alpha \mid \alpha \geq \alpha_2\right)d\alpha + BiS^{**}(y)\int_{\alpha_1}^{\alpha_2}\alpha S_b(\alpha,y) f\left(\alpha \mid \alpha_1 < \alpha < \alpha_2\right)d\alpha \quad (9)$$

and for girls

$$a_g = GiS^*(y)\int_{\alpha_4}^{1}\alpha f\left(\alpha \mid \alpha \geq \alpha_4\right)d\alpha + GiS^{**}(y)\int_{\alpha_3}^{\alpha_4}\alpha S_g(\alpha,y) f\left(\alpha \mid \alpha_3 < \alpha < \alpha_4\right)d\alpha, \quad (10)$$

where $BiS^*(y)$ [$GiS^*(y)$] is the share of enrolled male [female] students that are in school full time ($s_s = 1$) and $BiS^{**}(y)$ [$GiS^{**}(y)$] is the share of enrolled male [female] students that are in school less than full time ($0 < s_s < 1$). The first part of equation (9) [(10)] is the average ability of boys [girls] who are sent full-time to school weighted by the size of this group and the second part of the equation is the average ability of boys [girls] who are sent part-time to school weighted by the size of the group. The threshold values for α, for a given y and when $s_s = 1$, are $\alpha_2(y) = u'(y + \eta_g - 1)$ and $\alpha_4(y) = u'(y-2)\frac{\eta_g}{\theta_g}$. $s_s = S_s(\alpha, y)$ is the fraction of time spent in school for children not enrolled full time and s_s is a function of α and y and defined from the first-order condition (6).

Proposition 3 *a) The average innate ability of girls in school, α_g, will be higher than that of boys, α_b, although the girls' average cognitive skills, a_g, may not be higher. b) a negative income shock has two effects on average cognitive skills: (i) more marginal students drop out which will raise the average ability of the remaining students and (ii) less resources will be provided to the child, or less time will be spent in school, which will reduce the average ability. Which of the two effects dominates is ambiguous.*

How does an income shock affect average ability? As is evident from (9) and (10), even in this simple model, the total impact depends on a number of factors and it is difficult to derive closed form solutions. However, numerical simulations suggest that the resource effect dominates for low y, while the selection effect dominates for high y. Moreover, as long as a sufficient number of girls are in school, the effect is larger for girls than for boys.

Figure 2 depicts one of these numerical simulations [11]

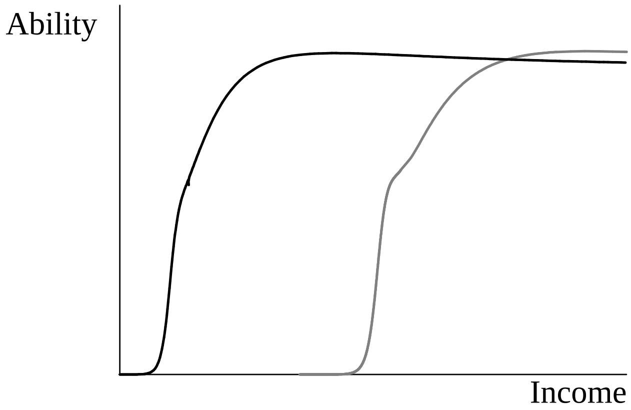

Figure 2: Average ability of girls and boys conditional on income.

In this particular example, for sufficiently low income levels there are no girls (gray line) enrolled in school. The average ability of boys (black line) is always higher than the average ability of girls up to some high level of income. For relevant parameter values (i.e. when more than 20 % and less than 80 % of the girls are enrolled in schools) $\frac{da_g}{dy} > \frac{da_b}{dy}$, an income shock will reduce the average ability of girls more than the average ability of boys.

4 Data

This paper uses and merges data from three different sources. Primary school data have been collected from the Ministry of Education and Sports (MOES) in Uganda. The assembled data include enrollment by gender, grade and year for the period 1992-2002 at the district level, for each of Uganda's approximately 50 districts. The underlying information is collected at the beginning of each year by the MOES from all primary schools and for all grades and is then aggregated to the district level.

Test score data have been collected from the Uganda National Examination Council. Obviously, a useful measure of students' cognitive skills must be comparable between all

[11] I simulate ability using the same parameter values and distribution function as in Figure 1.

schools and districts. Primary Leaving Exams (PLE) fulfill this requirement as these standardized tests are taken each year by all Grade 7 students in Uganda. The PLE provides test scores separately for Math, English, Science and Social Studies as well as an aggregate score. This paper will primarily focus on the aggregate test score for the years 1989 to 2002. One advantage of using PLE as a measure of cognitive skills is that passing the test is a requirement for acceptance into secondary school, so that students have strong incentives to do their very best. A possible disadvantage is that average PLE scores across districts may not display a great deal of variation. Note that the test score (unlike enrollment) data is available at the individual level.

Rainfall data, used as a proxy for household income, at the regional level have been collected from the Meteorological Department at the Ministry of Water, Land and Environment. To construct a rainfall shock variable, I use information on regional rainfall from 16 weather stations in Uganda. Monthly rainfall data have been collected from 1951 through 2003, but most stations did not start collecting until 1975; some stations also lack data for some months per year. I start by constructing a basic measure of total rainfall (in millimeter) by district d and year t, R_{dt}.[12] To construct a transitory rainfall variable, $(R_{dt} - \overline{R_d})$, it should also be known how current rainfall deviates from its expected value, $\overline{R_{dt}}$. If rainfall were serially correlated across years, $\overline{R_{dt}}$ would have to be forecasted for each region and year. However, I am unable to reject the hypothesis that rainfall follows a white-noise process for all districts but six. [13] Thus, I can set $\overline{R_{dt}} = \overline{R_d}$, historical rainfall over time in district d. My main rainfall shock variable is given by the difference $R_{dt-1} - \overline{R_d}$, which is the difference between actual rainfall in district d at time $t-1$ and historical rainfall in district d. Besides this core variable, I also experiment with several other rainfall shock measures, such as an indicator of rainfall at least 1.5 or 2 standard deviations from the historical mean.[14] Note that I have rainfall data for a longer time-period than the period for which I have corresponding enrollment and test score data.

Figure 8 depicts scatterplots of yearly rainfall in a subset of districts from different regions and rainfall zones in Uganda. The plots illustrate the large variation in yearly rainfall within districts and that the rainfall data are not auto-correlated.

[12] For further information on how the basic rainfall measure, R_{dt}, was constructed, see the Appendix.

[13] Excluding these districts in my sample does not quantitatively change the result.

[14] See the section on robustness analysis.

4.1 Descriptive statistics

Summary statistics on primary school enrollment by district for the period 1992-2002 is presented in Table 1. On average, more boys than girls are enrolled in all primary school grades and the sex imbalance in enrollment increases for higher grades. This can also be recognized from the gender fraction variable, which indicates the difference between male and female students over the total number of students in each grade. If an equal number of female and male students are enrolled, the gender fraction variable is 0. In Table 1, the gender fraction variable is positive for all grades and increases for higher grades. Further, in grade 1 there are, on average, 4 percent more boys than girls enrolled while in grade 7, the difference between female and male enrollment has increased to 25 percent.

Table 2 presents summary statistics on the rainfall shock variable used as a proxy for exogenous income shocks to households at the district level. The descriptive statistics is for the period 1975-2003. The rainfall shock variable $(R_{dt-1} - \overline{R_d})$, rainfall deviation from its historical mean, is by construction equal to 0 on average and the standard deviation is 194 millimeters (mm) per year. On average, it rains 1273 mm per district and year.

Table 3 presents descriptive statistics of Primary Leaving Exam (PLE) test scores for the years 1989-2002. The PLE test score ranges from 0 to 32 and the average test score is 11.25. On average, female students score 0.84 points worse than male students on the test. The average number of students taking the test per district and year is 8205.

5 Identification Strategy

The main problem in identifying the link between household's economic conditions and differential investments in children's education is that both may partly be related to omitted household characteristics. For example, suppose parents' health status is an important determinant of girls' schooling, i.e. a family with less healthy parents will need the girl to stay at home and assist in domestic work and accordingly, girls in less healthy families will be characterized by a higher drop out ratio as compared to girls in families with healthy parents. In addition, if the parents' health status is poor, this is likely to make them less successful on the labor market. Failure to control for differences in parental health status will bias the estimates since household income and girls' education are jointly determined by parental health status.[15] Omitted district-specific variables may also create some concern if, for example, households in some districts are more progressive than households in other districts (i.e. because of different cultural norms across ethnic groups), which could affect both girls' enrollment in primary school and household income.

I avoid these problems by looking at plausibly exogenous income shocks in Uganda across districts and over time. Uganda is an agricultural country and the mainly rainfed agricultural sector employs more than 90% of the workforce and therefore, rainfall shocks constitute a good proxy to household income shocks[16]. In an ideal setting, I would use rainfall as an instrument for household income in a first-stage regression and income as a determinant of investment in education in a second-stage regression. Unfortunately, district-specific income data over time are not available and I will therefore look at the reduced form relationship between rainfall shocks and investment in boys' and girls' education. However, national time-series data on crop production are available.[17] Table 13 and Figures 6 and 7 depict the relationship between the rainfall shock measure (at the national level, i.e. $(R_t - \overline{R})$ and the production of the main staple food, banana, and the main export crop, coffee. For both crops, $(R_t - \overline{R})$ enters highly significant and with the predicted positive sign.

Another concern with looking at the reduced form relationship between rainfall shocks and educational outcomes is the implicit exclusion restriction. However, it is unlikely that rainfall shocks would have a direct impact on educational choices that would have different effects on boys' and girls' schooling. One possible channel through which rainfall shocks could affect children's enrollment is through damaged infrastructure. However, the difficulty in attending school due to damaged roads would affect boys' and girls' enrollment equally. Alternatively, if the rainfall shock had damaged the family's house and the boy needed to stay at home and help rebuild the house, I would have a downward bias in my estimates. A second potential channel through which rainfall shocks could affect boys and girls' enrollment differently, is if there exists a specific disease occurring in periods of rainfall shocks and affecting girls and boys differently. According to the Ministry of Health in Uganda, there does not exist any such disease in Uganda and hence, this potential channel is also ruled out.

In the below analysis, I first consider the relationship between income shocks and primary

[15] In this example, the effect of income on girls' education would be overstated.

[16] Note that Miguel et al. (2004) find a close relationship between rainfall and GDP at the cross-country level.

[17] National data on crop production are available for the period 1979-2003.

school enrollment. More specifically, I test for differences in female and male enrollments in the wake of transitory shocks using the following regression:

$$Y_{dt} = \partial + \delta_t + \beta(R_{dt-1} - \overline{R_d}) + \varepsilon_{dt}, \tag{11}$$

where Y_{dt} is the measure of enrollment in district d and year t, $(R_{dt-1} - \overline{R_d})$ is the deviation in rainfall from the historical mean in district d and year $t-1$, δ_t represents time fixed effects and ε_{dt} is the error term. This regression is estimated for four different definitions of enrollment: female students, male students, total students and gender fraction, defined as $\frac{(male - female)}{total}$.

The identifying assumption in equation (11) is that the deviation in rainfall from its historical mean in period $t-1$, $(R_{dt-1} - \overline{R_d})$, is uncorrelated with the error term ε_{dt}, i.e. there are no omitted variables correlated with $(R_{dt-1} - \overline{R_d})$. Clearly, the education levels of girls and boys are affected by many other factors than income. Some of these factors may also be related to the pattern of rainfall over time. For example, districts with high average rainfall may be populated by more households and these households may, on average, have different characteristics than households in districts with less average rainfall (e.g. higher income, more progressive views toward women, etc.). These characteristics may, in turn, influence the education choice of boys and girls. However, by construction, my key explanatory variable, rainfall deviations from the historical mean, is orthogonal to mean rainfall. Thus, the fact that I exclude variables that are functions of average rainfall will not bias the estimate of $(R_{dt-1} - \overline{R_d})$. Similarly, districts with a high variation in rainfall (large standard deviation) may be populated by more risk-averse people and they may also have different preferences for optimal levels of education for girls and boys. However, the standard deviation of rainfall (in a district) is also orthogonal to $(R_{dt-1} - \overline{R_d})$.

Several other potential time-invariant variables may influence Y_{dt}. In principle, these could be controlled for by using district fixed effects. However, in this particular case, this comes at a large cost. Specifically, with district fixed effects, β is identified from the deviation in rainfall from mean rainfall in the period for which the enrollment data are available (1992-2002).[18] In other words, I exploit less than 40 percent of the available data on rainfall (1975-2003). As average rainfall will be less precisely estimated, this will affect the precision of the

[18] With district fixed effects, equation (11) becomes

$$Y_{dt} = \delta_d + \delta_t + \beta(R_{dt-1} - \overline{R_d}^L) + \varepsilon_{dt}, \tag{12}$$

estimate for β and more so in a fixed-effects specification. In the robustness and extension section, I nevertheless report the results using the smaller sample, i.e. estimates of (11) with district fixed effects.

In addition to studying the effect of income shocks on enrollment, I study the relationship between childhood malnutrition (or less school expenditures) caused by transitory shocks and cognitive achievement. Once more, I focus on differences between girls and boys. To this end, I use the following specification,

$$TS_{idt} = \partial + \delta_t + \theta_1 F_{id} + \theta_2 (R_{dt-1} - \overline{R_d}) + \theta_3 \left((R_{dt-1} - \overline{R_d}) * F_{id} \right) + \varepsilon_{idt}, \qquad (14)$$

where TS_{idt} is the test score of individual student i in district d and year t. δ_t are time fixed effects and ε_{idt} is the individual specific error component. F_{id} is a dummy variable indicating whether the student is female or male, $(R_{dt-1} - \overline{R_d})$ is the deviation in rainfall from the historical mean in district d and year $t-1$. In (14), the parameter of interest is θ_3 which gives an estimate of the potential gender bias in the quality of education.[19]

I assume the errors in (11) and (14) to be iid between districts, but allow them to be correlated within districts, i.e., I cluster the standard errors by district.

6 Results

6.1 Enrollment

Figure 5 depicts the correlation between district income and girls' and boys' enrollment in grade 7. Although the locally weighted regression does not provide any causal evidence, it reveals a relationship between income and enrollment similar to that predicted in the model. For low levels of income, very few girls attend school and there is a large gap between girls' and boys' enrollment. When at least 50 percent of the girls are enrolled in primary school,

where δ_d is a district fixed effect and $\overline{R_d}^L$ is the historical mean of rainfall in district d. Differencing away the fixed effects, equation (12) can be rewritten as

$$\left(Y_{dt} - \overline{Y_d}^S \right) = \beta (R_{dt-1} - \overline{R_d}^S) + \left(\varepsilon_{dt} - \overline{\varepsilon_d}^S \right), \qquad (13)$$

where superscript S denotes the short-run (1992-2002) mean.

[19] I am not able to estimate the effect on school level, since the collected raw data are only coded by district level.

an income shock will have a larger effect on girls than on boys (which is indicated by the slope of the curves) up to some high level of income.

As discussed in Section 5, the correlation depicted in Figure 5 is characterized by omitted variables. To study the causal effect of household income shocks on the investment in education conditional on gender, I use exogenous rainfall shocks as a proxy for household income. I start by studying how female and male enrollment in primary schools varies with exogenous income shocks. Table 4 reports the results of estimating equation (11) using the gender fraction measure as the dependent variable. For all grades, the estimate is negative which indicates that girls are more affected by rainfall shocks than boys and all coefficients are significantly different from 0 from grade 3 up to grade 7. From grade 4 and above, rainfall shocks have an exponential effect on investment in children's education conditional on gender and hence, students enrolled in higher grades are more affected by rainfall shocks than students enrolled in lower grades. The estimates suggest that a negative income shock of one standard deviation increases the fraction of male to female over the total number of students in grade 7 by 0.18 standard deviations, an effect that is significant at the 1 percent level.

The results in Table 4 could be driven by changes both in female and male enrollment. To better understand how rainfall shocks affect the gender fraction, I estimate regression (11) separately with female and male enrollment as dependent variables. The results from these regressions are reported in Tables 5a and 5b. The estimates in Table 5a suggest that negative rainfall shocks have large negative and highly significant effects on female enrollment in primary schools and the effects grow stronger for older girls. For example, a negative rainfall shock of one standard deviation cuts enrollment by 532 girls in grade 7 in a typical district and the effect is significant at the 1 percent level. This is a large effect corresponding to nearly 20 percent of the actual 2896 girls enrolled in grade 7 in the average district.

The results in Table 5b indicate that the effect on boys' enrollment is much smaller and only marginally significant. According to the point estimates, a negative income shock of one standard deviation leads to a reduction of 300 boys in grade 7 in the average district, which only corresponds to 8 percent of the average number of male students (3876). However, the effect is statistically insignificant.

Figure 9 depicts the results from a locally weighted non-parametric estimation on rainfall and female and male enrollment in grade 7. This graph visually shows the results indicated in Tables 5a and 5b. There are always more boys than girls enrolled. In periods of negative rainfall shocks, the ratio of boys to girls in primary school increases since girls are dropping out of school. This effect becomes stronger for larger negative rainfall shocks. When districts experience positive rainfall shocks, the ratio of boys to girls enrolled decreases and both more girls and boys enroll in primary school. For extreme positive rainfall shocks, there is a decrease in the enrollment of both boys and girls.

The model discussed in Section 3 highlights several mechanisms that could explain the differential investment in children's education. Can these mechanisms say something about what is driving the results? The returns to education (ω_s in the model) and the share of the child's income (as an adult) transferred to his/her parents (γ_s in the model) are not likely to be a function of the primary grade in which the student is enrolled. On the other hand, $\frac{\partial \eta_g}{\partial age} > 0$, girls' productivity in domestic work is increasing in age since older girls are able to perform more tasks and take on more responsibility in home production than younger girls. Thus, the evidence in Table 4 suggests that one of the key mechanisms behind the differential treatment of girls versus boys is related to the fact that parents' values of child labor (for home production) differ across sexes. That is, girls must bear the bulk of the additional work required at home in bad times.

Negative income shocks have a negative effect on girls' schooling, while boys remain relatively unaffected, but do income shocks have a permanent or temporary effect on enrollment? To study this, I examine how lagged rainfall shocks affect enrollment measured in gender fraction. Specifically, I include lagged rainfall shocks for two periods in regression (11) and the results are found in Table 6. If income shocks have a temporary effect on enrollment, students withdrawn from primary school in the year of an income shock will return to school in the following year, which will be indicated by a small, if not nil, value on the lagged variables. However, if income shocks have a permanent shock on enrollment, students who dropped out of primary school because of a negative income shock would remain absent also in the years following the rainfall shock and the coefficient on the lagged variable would be significant and relatively constant over time. The result depicted in Table 6 suggests that rainfall shocks have an irreversible effect on enrollment, conditional on gender. Rainfall shocks in previous periods affect enrollment in the current period and the effect remains relatively constant over time. For students in grade 5, negative rainfall shocks in the previous period have a positive effect on the male to female enrollment ratio which is significant at the 5 percent level. The coefficient value is similar to the current effect on rainfall shocks on students in grade 4, which suggests that girls withdrawn from school in grade 4 because of an income shock remain withdrawn in grade 5. Similarly, girls' relative to boys' enrollment in grade 7 is negatively affected by negative rainfall shocks that appeared when these students were in grades 5 and 6 (rainfall shocks lagged one and two periods) and these effects are significant at standard levels of significance. Graduating students in period t who were exposed to an income shock in period $t-2$, in grade 5, and dropped out, had not returned to school in grade 7. The finding suggests that negative income shocks result in a permanent marginalization of girls relative to boys with regard to schooling and this result applies to students in higher grades.

To summarize, the results clearly indicate that households respond to income shocks by varying the quantity of girls' education, while boys are to a large extent sheltered. This finding is consistent with the simple model presented above. The evidence further suggests that girls perceived higher productivity in performing domestic chores is the key mechanism behind these findings. Moreover, taking past rainfall shocks into account makes the effect of rainfall shocks on differential treatment in education even more important and suggests that rainfall shocks have a permanent effect on girls' enrollment relative to that of boys.

6.2 Educational achievements

Table 7 shows the results of estimating regression (14) which indicate that transitory income shocks do not only affect investment in children's education, but also children's performance. In periods of transitory income shocks when families are constrained by less resources and there are differences in girls' and boys' access to resources, this consequently affects children's learning. According to specification 1, a negative rainfall shock has a negative effect on test scores in general and the effect is significant at the 5 percent level. Girls score 0.79 points less than boys on the PLE and the interaction effect between female students and rainfall shocks indicates that girls are more affected by rainfall shocks as compared to boys. A negative rainfall shock of one standard deviation reduces the girls' test scores by 0.19 points, which corresponds to a decrease of 0.03 standard deviations in female test scores. Although precisely estimated, the effect is small. This would be consistent with the model in so far that the resource effect and the selection effect almost cancel out. In the model, a negative income shock has two effects on female students' performance: marginal girls will be withdrawn from school before marginal boys and the resources (food) provided will fall more for girls than for boys. Hence, the small effect of income shocks on female students' performance might be due to these two effects going in opposite directions. Only girls in the upper quintal make it through primary school and accordingly, girls with the highest cognitive skills reach grade 7 while boys belonging to both the upper and the lower quintal reach grade 7, since their schooling is prioritized within the household. This selection effect would cause girls to perform better on the test as compared to boys. On the other hand, girls are provided with less resources within the household or, alternatively, have to spend more time on domestic work as compared to boys and this resource effect causes girls to perform worse on the test as compared to boys. The results in Table 7 suggest the consumption effect to be marginally more important.

Similar to the enrollment data, it is important to understand whether income shocks have a permanent or temporary effect on students' performance. In specifications 2–4, I am including lagged rainfall to study whether rainfall shocks have a prolonged effect on academic performance. The result in Table 7 and specification (4) show that girls affected by rainfall shocks in previous periods perform worse on the PLE as compared to boys and this effect is constant over time. Thus, girls affected by rainfall shocks two years earlier, in the last year or in the current year all score approximately 0.08 less than boys and the effect is significant at the 10 percent level. These results suggest negative rainfall shocks to have an enduring effect on girls' performance in the Primary Leaving Exam.

7 Robustness analysis

As a robustness test, I am running regression (11) with controls for the long-term mean and variance and my results are robust, which should clearly be the case since the mean and variance of rainfall are, by construction, orthogonal to the key explanatory variable. In addition, regressing equation (11) with district fixed effects indicates that my results are robust to the inclusion of district fixed effects. The standard errors increase but the estimated effects are significant and similar to those reported above when constraining the sample to those districts with approximately similar long-term and short-term rainfall.[20]

To study the robustness of the key explanatory variable, I experiment with other rainfall shock measures alongside the core variable $(R_{dt-1} - \overline{R_d})$. Other rainfall shock measures used are rainfall deviations of at least 2 and 1.5 standard deviations from the historical mean and I also study the individual effect of positive and negative rainfall shocks. According to Table 12, the effect of rainfall shocks on female enrollment is maximized when using rainfall shocks larger than 2 standard deviations from the historical mean as the explanatory variable. According to specification (2), negative income shocks are driving this result. When using rainfall shocks larger than 1.5 standard deviations as the explanatory variable, positive and negative shocks have a similar effect on female enrollment.

I also investigate how extreme positive rainfall shocks affect enrollment, i.e. whether large positive rainfall shocks have a negative effect on enrollment. According to specification 5 in Table 12, a large positive rainfall shock i.e. a flood, decreases the enrollment of girls in school and the effect is significant at the 1 percent level. The result indicates that an extreme positive rainfall shock has a negative effect on enrollment and this pattern is consistent with that found for crop production (see Figures 6 and 7). I exclude extreme outliers and reestimate equation (11) and the effect becomes stronger, which implies that large positive shocks are pushing the measure effect of rainfall shocks towards zero.[21]

Finally, I have tested for non-linearity in the effect and find a non-significant result. In my regressions, I am assuming that rainfall shocks have a linear effect on enrollment and by testing for the polynomial effect, I investigate whether rainfall shocks have a diminishing or increasing marginal effect on enrollment. The coefficients on squared rainfall shocks (positive and negative) are close to zero and insignificant. According to the results, I can exclude the possibility that rainfall shocks have a non-linear effect on the enrollment of girls and boys.

[20] Three districts were dropped, since their long-term and short-term mean of rainfall differed significantly. If I had not dropped those districts, average rainfall for the 10-year period would have been less precisely estimated which, in turn, would have affected the precision of the estimate.

[21] Results are available upon request.

8 Conditional Findings

Uganda experienced a large primary education sector reform in the mid 1990s when the Government outlawed school fees in primary education, the so-called universal primary education reform (UPE). Under certain conditions (discussed below), I can use this policy experiment to estimate the effects of a reduction in the (formal) cost of schooling on the relative quantity and quality of boys' versus girls' education.

The UPE reform was implemented country-wide in 1997. Prior to this, all primary schools in Uganda charged user fees. To identify the effects of the reform on boys' versus girls' schooling, I estimate the following regression

$$Y_{dt} = \partial + \mu_1 UPE + \mu_2 (R_{dt-1} - \overline{R_d}) + \mu_3 \left[UPE * (R_{dt-1} - \overline{R_d}) \right] + \varepsilon_{idt}, \tag{15}$$

where Y_{dt} is the measure of enrollment in district d and year t, and μ_1 is the direct effect of lower school fees on education. Note that μ_1 is identified purely from the time-series variation. Clearly, this is not an uncontroversial identification strategy. There are other changes that could have occurred during the same time period as the UPE reform that could affect Y_{dt} and thus, cause biased estimates. Note, however, that no other (major) policy reform which could be affecting primary school enrollment was introduced at the same time. Still, the evidence should be viewed as suggested.

Tables 8a-8c report results from the regression determining the effect of the UPE reform on female and male enrollment as well as on the gender fraction variable. According to Tables 8a and 8b, the UPE reform had a large and positive effect on both female and male enrollment. It increased female enrollment by 0.30 to 0.44 standard deviations in all grades and similarly for males, the abolishment of user fees increased boys' enrollment by 0.26 to 0.40 standard deviations and the effects are significant at standard levels. To determine whether girls or boys are more affected by the reform, I re-estimate the regression using gender fraction as the dependent variable. Table 8c shows that female students are affected more by the UPE reform than male students and the effect is highly significant in all grades. In the years following 1997, girls' enrollment increased more relative to that of boys for all grades, compared to the years prior to 1997 and the effect is largest for lower grades. After the UPE reform, the gender fraction variable decreased by 0.31 standard deviations for students in grade 1.

Tables 9a to 9c determine whether household income shocks had different effects on girls' and boys' schooling before and after the abolishment of user fees. According to Tables 9b and 9c, negative income shocks had large and negative effects on female students after the UPE reform, significant at the 1 percent level for girls in higher grades, while boys' enrollment was not affected by an income shock after the abolishment of user fees. Table 9a depicts the results when using the gender fraction variable as the explanatory variable and it indicates that negative income shocks have a larger effect on girls' enrollment relative to that of boys after the UPE reform, compared to the effect before the UPE reform.

What can account for these results? Let us now return to the model formulated in Section 3. As illustrated in Figure 3, removing school-fees would lead to an inward shift of the BiS and GiS curves.[22] In the figure, the solid lines represent the enrollment of boys (black line) and girls (gray line) before user fees were abolished and the dashed lines represent the enrollment after the cost reduction.

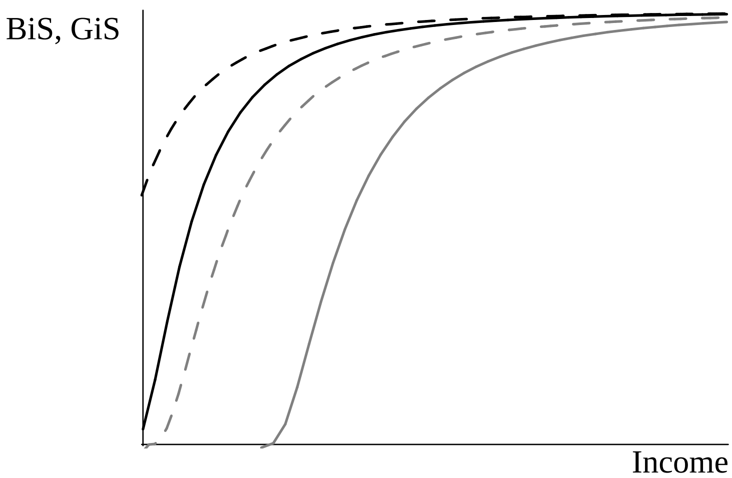

Figure 3: Enrollment of girls and boys after the abolishment of school fees.

If all households had the same income (and at least 50 percent of the girls were enrolled in school), the model suggests that the UPE reform would result in an increase in the enrollment of marginal students (both boys and girls), but also that the effects of an income shock would fall. However, I find the effect of a negative income shock on girls' enrollment to be larger after the UPE reform. In reality, of course, not all households within a district have the same

[22] I simulate ability using the same parameter values and distribution function as in Figure 1.

income. To illustrate this, consider the case with two population groups in each district; poor and less poor people. Prior to the abolishment of user fees, only the less poor group sent their girls to school while both the poor and the less poor group sent their boys to school. This is illustrated in Figure 4, where the vertical line to the right corresponds to the less poor group and the left vertical line illustrates the poor group.

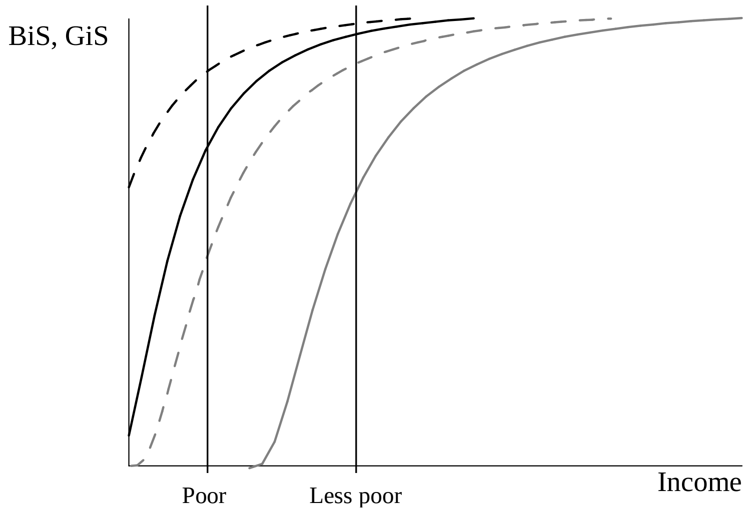

Figure 4. Enrollment of girls and boys after the abolishment of school fees, with two population groups in the district.

As a response to the cost reduction, the poor group starts sending its girls to school which increases the enrollment of marginal girls. Hence, the effect of an income shock after the UPE reform will be larger for girls than for boys than before the reform, since marginal girls who did not attend school before the UPE reform are now also affected. For boys, the effect will not be significantly different before and after the reform, since marginal boys were sent to school both before and after the UPE reform.

More insight into how income shocks affect households' differential investment in children's education is obtained by examining the impact in districts with different income levels. I am using a specification similar to (15) replacing the UPE dummy with a dummy for rich and poor districts when studying whether investment in children's education conditional on gender differs between districts with different income levels.[23] Table 10a shows the results for female students and it indicates that less girls are enrolled in the poorer districts as

[23] I do not have access to income data for all districts and therefore, the sample is slightly smaller in the regressions when income data are used.

compared to the more wealthy districts and the effect is significant for girls in grade 7. The result further indicates that the effect of a negative income shock is lower for girls in poorer districts as compared to girls in districts with an average income above the median. To exemplify, consider Figure 1 with poor and wealthy districts and two population groups in each district: poor and less poor people. In the wealthier districts, parents from both the poor and the less poor group send their girls and boys to school, while in the poorer districts parents in the poor group do not send their girls to school. Hence, the effect of an income shock on girls' enrollment will be larger in the wealthier districts as compared to the effect in the poorer districts, since also the marginal girls are affected. The results for boys are presented in Table 10b. A joint hypothesis test shows that it is not possible to say whether boys in poorer or wealthier districts are affected differently by a negative rainfall shock.

I am also studying whether the universal primary education reform as well as the income level in the district have an effect on children's academic performance and the results are reported in Table 11. According to specification (2), the UPE reform had no separate effect on students' performance. However, income shocks after the UPE reform had a large effect on test scores in general. After the abolishment of user fees, a negative income shock reduced test scores by 1.09 scores for all students, an effect which is significant at the 10 percent level. After the UPE reform, girls scored worse than boys compared to before the reform and this effect is significant at the 1 percent level, due to the fact that the UPE reform led to an increase in the enrollment of marginal girls who performed worse on the test as compared to the girls who attended school before the cost reduction.

Specification (3) in Table 11 determines the effect of rainfall shocks on students' academic performance conditional on the income level in the district. Students in districts with an income level below the median are performing worse on the PLE test as compared to students in the more wealthy districts and this effect is statistically significant at the 1 percent level. Girls score less than boys in general and the effect is stronger for females in the poorer districts. Girls in the poorer districts score 0.70 less than boys and this effect is significant at the 5 percent level. Students in the poorer districts score better than students in the more wealthy districts in the wake of a transitory income shock and this effect is significant at the 10 percent level. The explanation for this effect is similar to the explanation for the enrollment results, i.e. in the more wealthy districts, both girls and boys from the poor and the less poor group attend school while in the districts below the median income, girls in the poor group are not sent to school. In the wake of a transitory income shock, the effect on test scores will be larger in the wealthier districts, since students from both the marginal group and the less poor group are affected.

9 Conclusion

In many developing countries, boys are more likely to complete primary school than girls. Economists have long argued that boys' and girls' differential educational outcomes can be explained by underlying economic conditions. Methodologically, it is challenging to establish a link between household economic conditions and investments in children's education, since households' economic conditions and schooling may be associated with omitted variables such as health. The principal contribution of this paper is that it develops and implements a strategy capturing the causal effect of changes in households' economic conditions on the differential investment in children's primary education. In particular, it uses exogenous variation in rainfall across districts in Uganda to estimate the causal effects of household income shocks on children's enrollment and cognitive skills conditional on gender. I show that negative income shocks have large negative, and highly significant, effects on female enrollment in primary schools and the effects grow stronger for older girls. A decrease in rainfall of one standard deviation from its historical mean cuts female enrollment in grade 7 by 0.21 standard deviations. I find a smaller and only marginally significant effect on the enrollment of boys. Moreover, the findings suggest that negative income shocks result in a permanent marginalization of girls relative to boys with regard to schooling. Girls who have been withdrawn from school because of a negative income shock remain withdrawn in the years following the income shock. Additionally, I find that a negative income shock has an adverse effect on test scores in general and test scores of female students in particular. The results also suggest negative rainfall shocks to have an enduring effect on girls' performance in the Primary Leaving Exam. Girls affected by rainfall shocks in previous periods perform worse on the test as compared to boys and this effect is constant over time. The findings in this paper indicate that an exogenous transitory income shock to the household has a different effect, not only on investments in girls' and boy's education, but also on girls' and boys' academic performance. Moreover, income shocks have a permanent effect on girls' enrollment and academic achievements. The results imply that households respond to income shocks by varying the quantity and quality of girls' education, while boys are to a large extent sheltered – a finding consistent with a model where parents' values of child labor (in home production) differ across sexes.

I also find that the universal primary education reform introduced in 1997, which abolished user fees in all primary schools, had a large and positive effect on the enrollment of both boys and girls, although the effect is stronger for girls. The estimates on the gender fraction variable suggest that after the abolishment of school fees, the enrollment of female students in grade 1 increased by 0.31 standard deviations relative to the increase in boys' enrollment. After the abolishment of user fees in primary schools, a negative income shock had a larger effect on female students than before the reform, while boys' enrollment was still not affected.

The two main implications of the paper are (i) income is a key determinant of educational choices, in particular for girls; (ii) households appear to use girls for consumption smoothing in periods of negative income shocks, i.e. girls are perceived as a buffer and used as an insurance (for domestic work and reduced consumption) in periods of transitory shocks. Considering that gender equality has been identified as one of the most important goals of the donor community in the next decade, e.g. the Millennium Development Goal, my paper shows that policies boosting income and increasing access to insurance and saving options for households are likely to affect the speed of reaching the gender equality goal.

There are several extensions worth pursuing, including understanding and estimating the socioeconomic outcomes (fertility and maternity rates) for cohorts suffering from shocks.

References

[1] African Development Fund, 2005, "Uganda - Multi-sector country gender profile", Agriculture and rural development nort east and south region (ONAR).

[2] Alderman, Harold, Jere. R. Behrman, Victor Lavy, and Rekha Menon, 2001, "Child health and school enrollment: A longitudinal analysis", Journal of Human Resources, 36(1), pp. 185-205

[3] Alderman, Harold, Jere R. Behrman, David R. Ross, and Richard Sabot (1996), "Decomposing the gender gap in cognitive skills in a poor rural economy", *Journal of Human Resources* 31(1): 229-254.

[4] Banerjee, Abhijit, 2004, "Educational policy and the economics of the family", Journal of Development Economics, Vol. 74, pp. 3-32

[5] Becker, Gary, 1981, " A treatise on the family", Cambridge, Massachusetts: Harvard University Press

[6] Beegle, Kathleen, Rajeev H. Dehejia and Robert Gatti, 2003, "Child labor, income shocks, and access to credit", World Bank Policy Research Working Paper No. 3075

[7] Behrman, Jere R., 1988, "Intrahousehold allocation of nutrients in rural India: Are boys favored? Do parents exhibit inequality aversion?", Oxford Economic Papers, 40(1), pp. 32-54

[8] Behrman, JR and JC. Knowles, 1999, "Household income and child schooling in Vietnam", World Bank Economic Review, 13(2), pp.211-256

[9] Deaton, Angus, 1997, The analysis of household surveys: A microeconometric approach to development policy, Johns Hopkins University Press: Balitimore

[10] Duflo, Esther, 2000, "Child health and household resources in South Africa: Evidence from the Old Age Pension program", The American Economic Review, Vol. 90 (2)

[11] Edmonds V. Eric, 2004, "Does illiquidity alter child labor and schooling decisions? Evidence from household responses to anticipated cash transfers in South Africa", NBER Working Paper No. 10265

[12] Foster, Andrew, 1995, “Prices, credit constraints and child growth in low-income rural areas”, Economic Journal, 105(430), pp. 551-570

[13] Foster, Andrew and Mark R. Rosenzweig, 1996, "Technical change and human capital returns and investment: Evidence from the green revolution", American Economic Review, 11(4), pp. 931-953.

[14] Glewwe, Paul, 2002, "Schools and akills in developing countries: Education policies and socioeconomic outcomes, Journal of Economic Literature, 40(2), pp. 436-482

[15] Glewwe, Paul, Hanan G. Jacoby, and Elizabeth M. King, 2001, “Early childhood nutrition and academic achievement: A longitudinal analysis”, Journal of Public Economics, 81, pp. 345-368

[16] Jacoby, G. Hanan and Emmanuel Skoufias, 1997, "Risk, financial markets, and human capital in a developing country", The Review of Economic Studies, 64(9), pp. 311-35

[17] Jensen, Robert, 2000, ”Agricultural volatility and investment in children”, American Economic Review, 90(2), pp. 399-404

[18] Kingdon, Geeta Gandhi (2002), "The gender gap in educational attainment in India: how much can be explained?", *Journal of Development Studies* 39(2): 25-53.

[19] Miguel, Edward, 2005, “Poverty and witch killing”, Review of Economic Studies, 72(4), 1153-1172

[20] Miguel, Edward, Shanker Satyanath and Ernest Sergenti, 2004, "Economic shocks and civil conflict: An instrumental variables approach", Journal of Political Economy, 112(4), pp. 725-753

[21] Morduch, Jonathan, 1995, "Income smoothing and consumption smoothing", The Journal of Economic Perspectives, 9(3), pp. 103-114

[22] Paxson, Christina H., 1992, "Using weather variability to estimate the response of savings to transitory income in Thailand", The American Economic Review, Vol. 82 (1)

[23] Rose, Elaine, 1999, “Consumption smoothing and excess female mortality in rural India”, Review of Economics and Statistics, 81(1)

[24] Rosenzweig, Mark R., and T. Paul Schultz, 1982, "Market opportunities, genetic endowments, and intrafamily resource distribution: Child survival in rural India", American Economic Review, 72(4), pp. 803-815

[25] Sen, Amartya, 1990, "More than 100 million women missing", New York Review of Books.

[26] Summers, Lawrence, 1994, "Investing in all the people", World Bank Policy Research Working Paper No. 905

[27] Qian Nancy, 2005, "Missing women and the price of tea in China: The effect of relative female income on sex imbalance", mimeo, Brown University

[28] The World Bank, 2002, "Achieving universal primary education in Uganda: The 'Big Bang' approach", Human Development Network

[29] The World Bank, 1993, "Uganda growing out of poverty", A World Bank Country Study

A Appendix

A.1 Proof of Proposition 1

The optimal intra-household choices for a girl's and a boy's education are determined by the following first-order conditions:

$$-u'\left[c_1\right] + \alpha_b^i \leq 0 \;\; \text{for } s_b \in [0,1] \tag{16}$$

$$-u'\left[c_1\right]\eta_g + \alpha_g^i \theta_g^i \leq 0 \;\; \text{for } s_g \in [0,1]. \tag{17}$$

Given assumption $\theta_g^i < \theta_b^i = 1$, $\eta_g > \eta_b = 1$ and $\alpha_g^i = \alpha_b^i = \alpha^i$, it follows that $\alpha_g^i \theta_g^i < \alpha_b^i$ and $u'(c_1)\eta_g > u'(c_1)$; the marginal cost for the girl's schooling is higher and the marginal gain is lower as compared to the boy's schooling. When y is sufficiently high, $y_1 = u_c'^{-1}\left[\alpha_b^i\right] - \eta_g$, so that it is not optimal to choose $s_b^i = s_g^i = 0$, then $s_b^i > 0$. The household will increase the boy's schooling until $s_b^i = 1$ when $y_2 = u_c'^{-1}\left[\alpha_b^i\right] + 1 - \eta_g$. Thereafter, (16) does not hold and the only way of transferring funds to the next period is by sending the girl to school which happens at $y_3 = u_c'^{-1}\left[\frac{\alpha_g^i \theta_g^i}{\eta_g}\right] + 2 - \eta_g$. The girl's schooling increases until $s_g^i = 1$ when $y_4 = u_c'^{-1}\left[\frac{\alpha_g^i \theta_g^i}{\eta_g}\right] + 2$.

If $s_g^i > 0$ and $s_b^i > 0, y_4 = u_c'^{-1}\left[\frac{\alpha_g^i \theta_g^i}{\eta_g}\right] + 1 - \eta_g$, a reduction in y will force the parents to decrease s_g^i on the margin. Parents will decrease s_g^i until $s_g^i = 0$ and only then will they start to decrease s_b^i. The girl's ability, $a_g^i = \alpha_g^i s_g^i$, is primarily affected by a reduction in y since parents choose to decrease s_g^i when y decreases.

A.2 Construction of Rainfall Measure

Uganda has 16 demarcated rainfall zones and 31 rainfall stations. Thus, each rainfall zone has on average 2 rainfall stations. The rainfall stations collect monthly precipitation in millimeters which is compiled by the Department of Meteorology. Most stations have collected monthly precipitation from the mid 1970 until today, although some stations have monthly precipitation from 1950 until today. Each rainfall zone contains on average three districts and most districts are located within the boundaries of one rainfall zone but some few districts are divided into two rainfall zones.

The Department of Meteorology provided me with a detailed map of Uganda showing the demarcated rainfall zones as well as the location of the 31 rainfall stations. I also received data on monthly rainfall for all rainfall stations in Uganda for all years. I merged the map of demarcated rainfall zones with a map of the district boundaries in Uganda to determine which districts are located in which rainfall zones and which rainfall stations are located in which districts.

Three distinct rules have been used when determining each district's rainfall. The rules are set so as to use all possible rainfall stations in the most accurate way and generate as much variation across districts as possible. First, districts that are located within one rainfall zone and have a rainfall station located in the district are assigned to have yearly rainfall according to this specific station. Approximately 70 percent of the districts in Uganda fall into this category. Second, for districts that are located within one rainfall zone but do not have their own rainfall station, I have used average yearly rainfall in the rainfall zone. Third, for districts located in two rainfall zones, I have calculated average yearly rainfall in the two zones and use this as a measure of yearly rainfall in the district. This rule also applies if the district has its own rainfall station but more than one fifth of the district is located in another rainfall zone.

For each district, I constructed a rainfall measure of total rainfall (in millimeter) by district d and year t, R_{dt}, by summing the monthly precipitation in the district over the 12-month period. Some stations lack data for some months per year and if more than one month is missing for a specific year, this is indicated by a missing value for that specific year.

Table 1. Descriptive statistics on enrollment by district, for the period 1992-2002

	Mean	Median	St.dev	Max	Min	Obs
Gender fraction P1	0.066	0.032	0.131	0.902	-0.543	490
Gender fraction P2	0.041	0.022	0.079	0.864	-0.329	490
Gender fraction P3	0.054	0.026	0.087	0.752	-0.140	490
Gender fraction P4	0.066	0.032	0.096	0.428	-0.061	490
Gender fraction P5	0.086	0.054	0.120	0.588	-0.106	490
Gender fraction P6	0.118	0.079	0.140	0.521	-0.085	490
Gender fraction P7	0.178	0.135	0.182	0.182	-0.254	490
Female students in P1	14740	12167	10486	64899	1258	490
Female students in P2	9612	8063	6668	4103	719	490
Female students in P3	8768	7329	6123	31266	327	490
Female students in P4	7391	6151	5266	25480	255	490
Female students in P5	5933	4734	4479	22902	171	490
Female students in P6	4489	3421	3587	19317	127	490
Female students in P7	2896	2167	2450	14065	96	490
Male students in P1	15355	12509	10950	75496	2124	490
Male students in P2	10219	8646	7048	50508	886	490
Male students in P3	9369	8148	6165	39483	545	490
Male students in P4	8027	7038	5303	29452	363	490
Male students in P5	6652	5671	4535	22248	207	490
Male students in P6	5308	4410	3764	18545	143	490
Male students in P7	3876	3183	2811	13923	132	490

a. Gender fraction=((male-female)/total student)

b. Descriptive statistics is **the** average per district for the period 1992 to 2002

Table 2. Descriptive statistics on rainfall

	Rainfall deviation (1975-2003)	Average rainfall (mm) (1975-2003)
Mean	0.00	1273
Median	-10.05	1254
St.dev	194	345
Max	746	2744
Min	-640	352
Obs	1296	1296

a. Descriptive statistics is the average for all years when rainfall data are available (1975-2003)

Table 3. Descriptive statistics on Primary Leaving Exam (PLE) test score data 1989-2002.

	Mean	Median	St.dev	Max	Min	Obs
Aggregate test score	11.25	10	8.38	32	0	1988884
Aggregate test score female students	10.75	10	8.46	32	0	816603
Aggregate test score male students	11.59	11	8.32	32	0	1169007
Total students taking the PLE per district and year	8205	7266	4892	21604	52	1988884
Female students taking the PLE per district and year	3893	3227	2667	11005	17	816603
Male students taking the PLE per district and year	4398	4042	2272	9926	19	1169007

a. Descriptive statistics is the average per district for the period 1989 to 2002 of the P7 students taking the Primary Leaving Exam

Table 4. The effect of rainfall shocks on gender fraction enrollment

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	-0.001	-0.001	-0.005**	-0.007***	-0.008**	-0.012***	-0.017***
(100 mm)	(0.002)	(0.002)	(0.0025)	(0.0025)	(0.003)	(0.004)	(0.006)
Rainfall deviation in	-0.03	-0.09	-0.13**	-0.15***	-0.13**	-0.16**	-0.18**
standard deviations	(0.06)	(0.18)	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)
(beta coeff.)							
R^2	0.22	0.39	0.40	0.45	0.47	0.54	0.75
Observations	409	409	409	409	409	409	409

a. Dependent variable is gender fraction enrollment for each primary level; ((male-female)/student) for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. All regressions include year dummies.
d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 5a. The effect of rainfall shocks on female student enrollment

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	404	303	467**	419**	377**	340***	274***
(100 mm)	(371)	(214)	(195)	(153)	(132)	(109)	(79)
Rainfall deviation in	0.07	0.09	0.14**	0.15**	0.16**	0.18**	0.21**
standard deviations (beta coeff.)	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
R^2	0.75	0.77	0.77	0.72	0.67	0.76	0.78
Observations	410	410	410	410	410	410	410

a. Dependent variable is female student enrollment for each primary level for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. All regressions include year dummies.
d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 5b. The effect of rainfall shocks on male student enrollment

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	327	266	352*	306*	269*	216*	155
(100 mm)	(373)	(232)	(199)	(168)	(148)	(125)	(97)
Rainfall deviation in	0.06	0.07	0.11*	0.11*	0.11*	0.11*	0.10
standard deviations (beta coeff.)	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
R^2	0.75	0.76	0.78	0.78	0.76	0.74	0.72
Observations	410	410	410	410	410	410	410

a. Dependent variable is male student enrollment for each primary level for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. All regressions include year dummies.
d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 5c. The effect of rainfall shocks on total student enrollment

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	733	563	819*	728**	650**	559**	432**
(100 mm)	(751)	(447)	(392)	(319)	(276)	(229)	(168)
Rainfall deviation in	0.07	0.08	0.13*	0.13**	0.14**	0.14**	0.16**
standard deviations (beta coeff.)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
R^2	0.75	0.76	0.78	0.78	0.76	0.74	0.72
Observations	410	410	410	410	410	410	410

a. Dependent variable is total student enrollment for each primary level for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. All regressions include year dummies.
d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 6. The effect of rainfall shocks on gender fraction enrollment, controlling for lagged rainfall

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	-0.001	-0.002	-0.004**	-0.006**	-0.007**	-0.010***	-0.014***
(100 mm)	(0.002)	(0.002)	(0.0025)	(0.0025)	(0.003)	(0.004)	(0.005)
Rainfall deviation (t-1)	-0.002	-0.003	-0.002	-0.003	-0.006**	-0.008***	-0.013***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)
Rainfall deviation (t-2)	-0.001	-0.001	-0.001	-0.002	-0.004	-0.007**	-0.014**
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
R^2	0.27	0.40	0.40	0.45	0.44	0.48	0.55
Observations	354	354	354	354	354	354	354

a. Dependent variable is gender fraction in enrollment for each primary level; ((male-female)/student) for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. All regressions include year dummies.
d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 7. The effect of rainfall shocks on Primary Leaving Exam test score

Specification	(1)	(2)	(3)	(4)
Rainfall deviation	0.25**	0.26**	0.25**	0.26**
(100 mm)	(0.10)	(0.10)	(0.11)	(0.11)
Female student	-0.79***	-0.84***	-0.79***	-0.83***
	(0.26)	(0.26)	(0.26)	(0.26)
Female*Rainfall dev	0.10**	0.10*	0.09**	0.08*
	(0.048)	(0.48)	(0.04)	(0.05)
Rainfall deviation (t-1)		0.02		0.01
(100 mm)		(0.11)		(0.11)
Rainfall dev (t-1)*Female		0.06*		0.07*
		(0.032)		(0.039)
Rainfall deviation (t-2)			0.08	-0.08
(100 mm)			(0.11)	(0.11)
Rainfall dev (t-2)*Female			0.08*	0.08*
			(0.04)	(0.045)
R^2	0.01	0.01	0.01	0.01
Observations	1664786	1592209	1517862	1473785

a. Dependent variable is district average PLE test scores for the years 1989-2002.
b. Robust standard errors in parenthesis.
c. Specification: (1) Year fixed effects included in regression (2) Lagged one time period, (3) Lagged two time periods, (4) Lagged rainfall one and two periods included simultaneously in the regression.
d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 8a. The effect of the UPE reform on female enrollment (reported in beta coefficients).

	P1	P2	P3	P4	P5	P6	P7
UPE	0.30**	0.44***	0.43**	0.44***	0.43***	0.41***	0.36**
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
R^2	0.09	0.19	0.18	0.20	0.19	0.24	0.13
Observations	490	490	490	490	490	490	490

a. Dependent variable female enrollment for each primary level and the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 8b. The effect of the UPE reform on male enrollment (reported in beta coefficients).

	P1	P2	P3	P4	P5	P6	P7
UPE	0.26***	0.39***	0.38***	0.40***	0.40***	0.38***	0.31**
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
R^2	0.15	0.15	0.15	0.16	0.16	0.15	0.10
Observations	490	490	490	490	490	490	490

a. Dependent variable is male enrollment for each primary level and for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 8c. The effect of the UPE reform on gender fraction enrollment (reported in beta coefficients).

	P1	P2	P3	P4	P5	P6	P7
UPE	-0.31***	-0.37***	-0.37***	-0.35***	-0.30***	-0.24***	-0.20**
	(0.06)	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)	(0.04)
R^2	0.10	0.14	0.14	0.12	0.09	0.06	0.04
Observations	490	490	490	490	490	490	490

a. Dependent variable is male enrollment for each primary level and for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 9a. The effect of the UPE reform on gender fraction enrollment, controlling for income shocks and interaction effect (reported in beta coefficients)

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	-0.05	0.09	0.03	-0.01	0.02	0.02	0.03
	(0.09)	(0.08)	(0.08)	(0.06)	(0.07)	(0.08)	(0.09)
UPE	-0.28***	-0.44***	-0.37***	-0.35***	-0.29***	-0.23***	-0.17***
	(0.06)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.05)
UPE*Rainfall dev	-0.02	-0.14*	-0.14**	-0.11	-0.15*	-0.17*	-0.23***
	(0.06)	(0.074)	(0.07)	(0.08)	(0.09)	(0.09)	(0.08)
R^2	0.08	0.21	0.17	0.15	0.11	0.09	0.08
Observations	410	410	410	410	410	410	410

a. Dependent variable is gender fraction enrollment for all primary levels and for the years 1992-2002.

b. Robust and clustered standard errors in parenthesis.

c. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 9b. The effect of the UPE reform on female enrollment, controlling for income shocks and interaction effect (reported in beta coefficients)

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	0.22***	0.06	0.06	0.04	0.02	0.01	-0.016
	(0.06)	(0.04)	(0.05)	(0.04)	(0.04)	(0.08)	(0.05)
UPE	0.30***	0.44***	0.44***	0.45***	0.44***	0.41**	0.35**
	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
UPE*Rainfall dev	-0.09	0.07	0.09	0.09	0.12*	0.16***	0.22***
	(0.08)	(0.07)	(0.06)	(0.07)	(0.07)	(0.07)	(0.08)
R^2	0.12	0.22	0.22	0.23	0.23	0.21	0.18
Observations	410	410	410	410	410	410	410

a. Dependent variable is female enrollment for all primary levels and for the years 1992-2002.

b. Robust and clustered standard errors in parenthesis.

c. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 9c. The effect of the UPE reform on male enrollment, controlling for income shocks and interaction effect (reported in beta coefficients)

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	0.06***	0.08*	0.07	0.05	0.04	0.02	0.01
	(0.08)	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
UPE	0.25***	0.39***	0.39***	0.42***	0.41***	0.32**	0.32**
	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
UPE*Rainfall dev	-0.10	0.04	0.04	0.05	0.06	0.08	0.08
	(0.07)	(0.07)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
R^2	0.09	0.17	0.17	0.19	0.19	0.17	0.12
Observations	410	410	410	410	410	410	410

a. Dependent variable is male enrollment for all primary levels and for the years 1992-2002.

b. Robust and clustered standard errors in parenthesis.

c. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 10a. The effect of rainfall shocks and female enrollment controlling for districts with income less than the median (reported in beta coefficients).

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	0.11**	0.12**	0.20***	0.21**	0.21***	0.24***	0.28***
	(0.04)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
Income < 50th percentile	-0.05	-0.03	-0.01	-0.04	-0.09	-0.15	-0.22**
	(0.11)	(0.11)	(0.14)	(0.11)	(0.11)	(0.11)	(0.11)
Income*Rainfall dev	-0.06	-0.06	-0.09	-0.10*	-0.10*	-0.11**	-0.13**
	(0.08)	(0.06)	(0.07)	(0.05)	(0.05)	(0.05)	(0.05)
R^2	0.75	0.77	0.78	0.78	0.76	0.74	0.70
Observations	404	404	404	404	404	404	404

a. Dependent variable is female enrollment for all primary levels and for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. All regressions include year dummies.
d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 10b. The effect of rainfall shocks and male enrollment controlling for districts with income less than the median (reported in beta coefficients).

	P1	P2	P3	P4	P5	P6	P7
Rainfall deviation	0.10**	0.12**	0.16**	0.18***	0.17***	0.17***	0.18***
	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)
Income < 50th percentile	0.09	0.09	0.07	0.07	0.08	0.06	0.09
	(0.12)	(0.12)	(0.11)	(0.11)	(0.12)	(0.12)	(0.13)
Income*Rainfall dev	-0.06	-0.07	-0.09	-0.10	-0.10	-0.11*	-0.13*
	(0.07)	(0.06)	(0.07)	(0.06)	(0.07)	(0.06)	(0.07)
R^2	0.75	0.77	0.78	0.79	0.78	0.76	0.73
Observations	404	404	404	404	404	404	404

a. Dependent variable is male enrollment for all primary levels and for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. All regressions include year dummies.
d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 11. The effect of rainfall shocks on Primary Leaving Exam test score and controlling for conditional effects.

Specification	(1)	(2)	(3)
Rainfall deviation	0.25**	0.38	0.11
(100 mm)	(0.10)	(0.29)	(0.08)
Female student	-0.79***	-0.42	-0.97***
	(0.26)	(0.23)	(0.15)
Female*Rainfall deviation	0.10**	0.004	0.10
	(0.048)	(0.04)	(0.06)
UPE*Rainfall deviation		1.09**	
(100 mm)		(0.50)	
UPE*Female		-0.85***	
		(0.18)	
UPE		-0.45	
		(0.86)	
UPE*Female*Rainfall dev		0.17	
(100 mm)		(0.11)	
Income < 50th percentile			-3.02***
			(0.94)
Income*Female			-0.70**
			(0.31)
Income*Rainfall dev			-0.39*
(100 mm)			(0.20)
Income*Female*Rainfall dev			0.07
(100 mm)			(0.15)
R^2	0.01	0.02	0.04
Observations	1664786	1664786	1655184

a. Dependent variable is district average PLE test scores.

b. Robust standard errors in parenthesis.

c. Specification: (1) Only year fixed effects included in regression, (2) Controlling for UPE, (3) Controlling for districts with an average income below the median level in the country.

d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 12. The effect of extreme rainfall shocks on female enrollment in P7

	Dependent variable: Female enrollment in grade 7				
Specification	(1)	(2)	(3)	(4)	(5)
Rainfall deviation	3.94**				
> 2 stdev from mean	(1.82)				
Negative rainfall deviation		3.67**			
> 2 stdev from mean		(1.59)			
Positive rainfall deviation		4.15			
> 2 stdev from mean		(2.81)			
Rainfall deviation			2.50**		
> 1.5 stdev from mean			(1.02)		
Negative rainfall deviation				2.07*	
> 1.5 stdev from mean				(1.10)	
Positive rainfall deviation				2.76**	
> 1.5 stdev from mean				(1.26)	
Extreme positive rainfall deviation					-1.75***
>700 mm from mean					(0.29)
R^2	0.66	0.66	0.66	0.66	0.65
Observations	410	410	410	410	410

a. Dependent variable is female enrollment in primary 7 and for the years 1992-2002.
b. Robust and clustered standard errors in parenthesis.
c. All regressions include year dummies.
d. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Table 13. The effect of rainfall shocks on crop production at the national level.

	Coffee	Bananas	Peas
Rainfall deviation	3409**	6.04**	0.017**
at the national level	(1397)	(2.68)	(0.008)
R^2	0.23	0.18	0.19
Observations	23	24	24

a. Dependent variable is average crop production in the country for the years 1977-2002 for coffee and 1978-2002 for bananas and peas.

b. Robust and clustered standard errors in parenthesis.

c. *** [**] (*) denote significance at the 1, [5] and (10) percent level.

Figure 5. Correlation between district income and enrollment in grade 7.

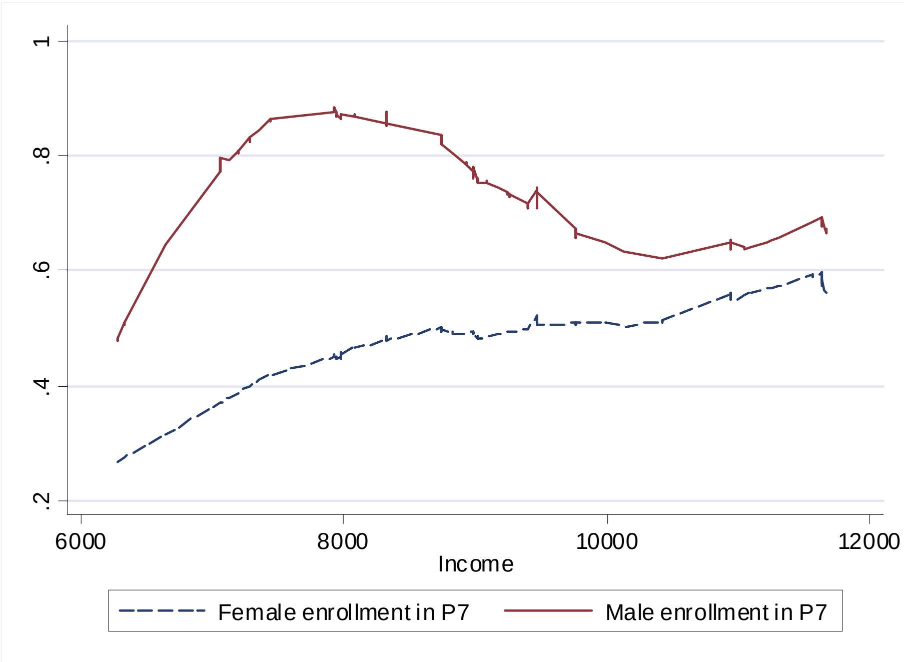

Figure 6. The effect of rainfall shocks on coffee production at the national level.

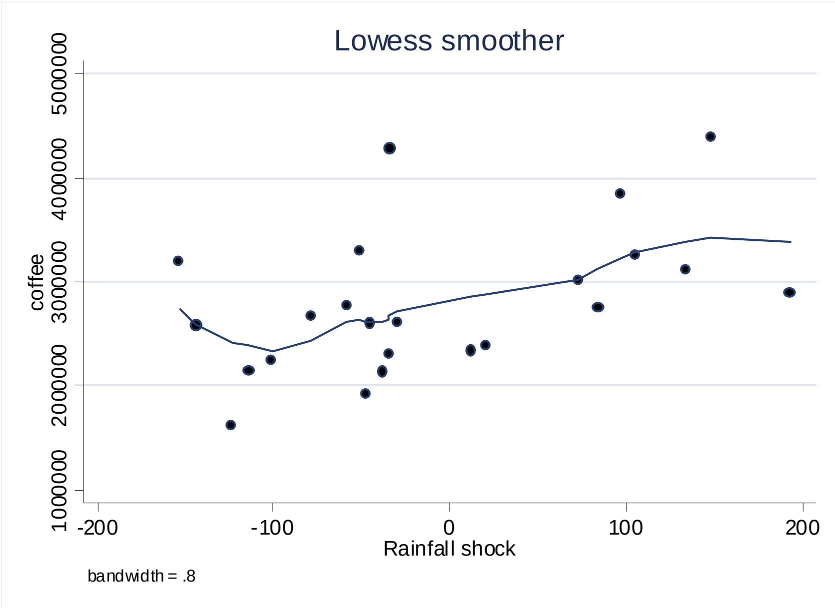

Figure 7. The effect of rainfall shocks on banana production at the national level.

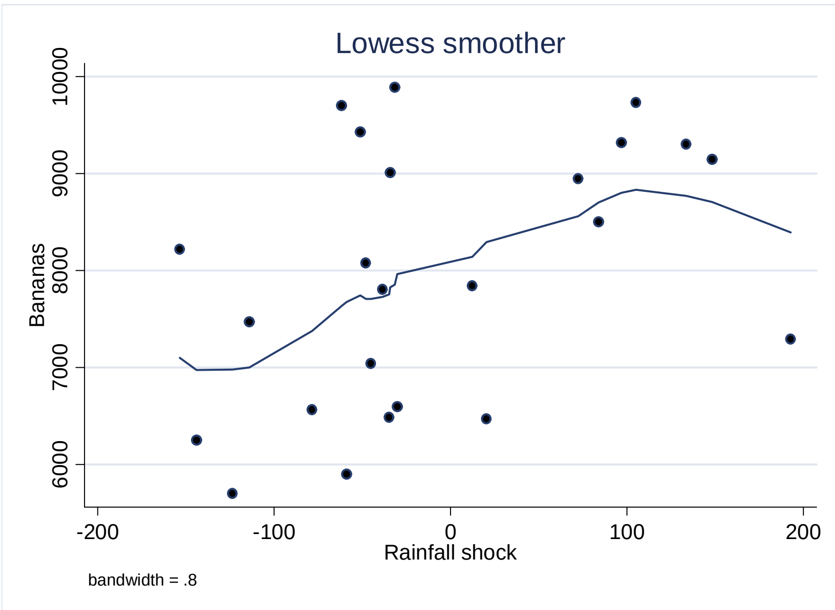

Figure 8. Scatterplots of average yearly rainfall for some sample districts.

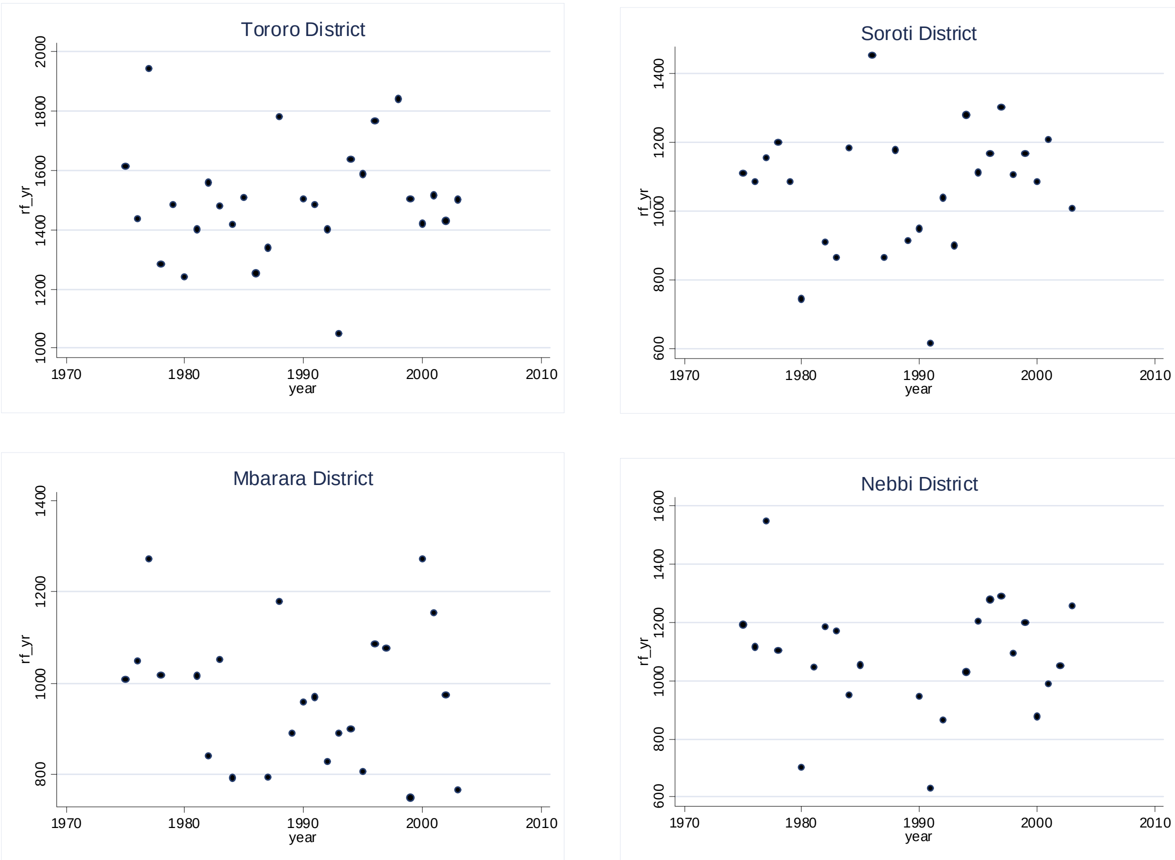

Figure 9. Locally weighted regression on rainfall and female and male enrollment.