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# Women's Relative Earning Power and Fertility: Evidence from Climate Shocks in Rural Madagascar *

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**Abstract**

The unified growth theory (Galor and Weil (1996)) suggests that a high gender gap in earning power increases fertility rates. This paper presents the first micro-founded test of this hypothesis, focusing on the critical age interval where this theory binds. Using household data from rural Madagascar—where restrictive gender norms and reliance on rainfed agriculture are prevalent—we exploit temporal and spatial variations in rainfall deficits at the grid-cell level during the growing season to measure women's relative economic opportunities. Our analysis, controlling for grid-cell and year-of-birth fixed effects and accounting for the spatial correlation of drought episodes, reveals that drought significantly increases completed fertility only when experienced during adolescence. We show that school dropout among adolescent girls and the widening gender gap in economic opportunities drive this increase. Moreover, drought exposure raises adolescent girls' marriage hazards and the likelihood of having multiple sex partners, triggering early childbearing, especially in agricultural households without irrigation. This study supports the unified growth theory by linking negative climate shocks to women's relative earning power and fertility decisions, highlighting the need for policies addressing gender disparities and environmental vulnerabilities.

**JEL**: C12, C13, C14, J12, J13, J16, O12.
**Keywords:** Drought; rainfed Agriculture; Women's earning power; Completed fertility.

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# 1 Introduction

The historical link between economic prosperity and demographic transition, particularly the decline in fertility rates, is well documented. Western countries have undergone this transition, and regions like Latin America and Asia are experiencing accelerated transitions. In contrast, sub-Saharan Africa lags behind, with fertility rates in 2021 still double the global average.

The unified growth theory (UGT) proposed by Galor and Weil (1996) significantly contributes to understanding these regional disparities. Their pioneering work predicts that a technologically driven narrowing of the gender gap in earning power reduces fertility. Despite the importance of this prediction, there is surprisingly limited micro-level causal evidence to support it, particularly in high-fertility developing countries where gender norms restrict women's economic opportunities relative to men. Additionally, given that women's fertility horizon is finite, understanding the age interval at which this theory binds can enhance public policy effectiveness.

This paper tests the UGT's fertility hypothesis in the context of rainfed agricultural areas, known for high fertility rates, where gender norms increase women's dependence on rainfed agriculture for their livelihood compared to men. We estimate the effect of drought—a climate shock known to reduce labor productivity in agriculture (Dinkelman, 2017; Kaur, 2019; Feeny et al., 2021)—on the completed fertility of women in these areas and explore the age interval driving this effect.

Several factors motivate our exploration of age-based heterogeneous effects of drought on completed fertility. First, younger women might have more energy to invest in child-rearing than older women. The perceived physical and emotional energy required to raise a child may increase with age, thus raising the marginal cost of having another child. Second, older women are more likely to have accumulated assets that diversify their income sources. Consequently, taking time off for childbearing and rearing may represent a higher opportunity cost for them in terms of lost income.

The setting of our hypothesis testing is rural Madagascar. We use micro-level data from multiple sources, including several rounds of the Madagascar Demographic and Health Survey (DHS), the longitudinal Madagascar Young Adult Survey (MYAS), and the Academic Performance in Madagascar Survey (EPSPAM). Using DHS, we estimate a linear fixed-effect model of whether drought affects the completed fertility of a rural woman exposed to it during her reproductive years. We follow the literature (Shah and Steinberg, 2017; Kaur, 2019) in measuring drought in each locality as a normalized deviation of rainfall intensity below the $20^{th}$ percentile during the rainy season.[1]

Furthermore, given drought's tendency to cluster in space, we account for spatial correlation and control for grid cell fixed effects. We regress the completed fertility of a woman aged $44-49$ on a binary variable of whether she was exposed to drought at a specific stage of her reproductive years, including at age $15-19$ known as the adolescent stage, $20-24$, $25-29$, $30-34$, and $35-40$. To the best of our knowledge, this is the first study to consider the role played by the stage in a woman's lifecycle, in which she experiences an income shock.

Estimation results show that being exposed to drought during adolescence ($15-19$) while living in a rural rainfed agricultural area increases a woman's completed fertility by about 0.50 children. This positive fertility effect is consistent with the UGT's prediction. However, this effect is not observed in later age intervals ($20-24$, $25-29$, $30-34$, and $35-40$), for which estimations results do not show a statistically significant impact on fertility. This suggests the existence of a specific age interval at which the UGT's hypothesis binds.

This age-specific effect of drought on completed fertility may be explained by the fact that, in the context of rural communities of the developing world, most women older than 19 are already married or in long-term relationships. For these women, the onset of childbearing might have preceded their exposure to drought because the timing of childbearing often tracks closely with the timing of marriage in rural areas of the developing world, influenced by cultural norms of union formation and childbearing (Schuler et al., 2006; Avogo and Somefun, 2019). That drought increases completed fertility only among women exposed to it during adolescence is consistent with macro-level evidence show-

[1]We conducted several robustness checks using other drought measures, which did not change our findings qualitatively.

ing a negative correlation between age at first birth and total fertility rates (see Figure 1 in the Appendix section), with such a correlation being particularly steep for ages at birth approximately younger than 20 years old.

At this point, one may raise the issue of what potential micro-level mechanisms, if any, drive the effect of drought on fertility timing. In other words, why does drought induce fertility among adolescent girls?

First, to the extent that, as the literature finds, drought is an adverse productivity shock in rainfed agricultural areas (Dinkelman, 2017; Kaur, 2019), it may cause affected households to pull their daughters out of school due to lack of resources. Indeed, in patrilocal rural communities of sub-Saharan Africa, drought is known to induce differential parental investments in offspring based on gender, increasing girls' school dropouts relative to boys of the same age group (Dessy et al., 2023b), notably among adolescents whose schooling is subject to payment of tuition fees or is no longer compulsory (Dessy et al., 2023a). We test this first step of our mechanism using the MYAS and EPSPAM. Estimation results show that exposure to drought reduces rural adolescent girls' school enrolment by nearly 7 percentage points, and the result is statistically significant.

Second, rural adolescent girls forced to drop out of school due to drought may face gender-based restrictions in accessing economic opportunities compared to boys due to gender norms that restrict women's access to productive assets (Gray, 1993; Quisumbing et al., 2004; Doss et al., 2014; Meinzen-Dick et al., 2014; Ncube et al., 2018) and to labor migration (Agesa and Agesa, 1999; Lundgren et al., 2018; Evertsen and van der Geest, 2020). Moreover, as schooling is known to enhance women's economic livelihoods more than men's (Dougherty, 2005), dropping out of school early also directly exacerbates the employment opportunity gap favoring boy-over-girl dropouts. We test this second part of our mechanism using the MYAS and EPSPAM data and multiple rounds of Madagascar DHS. Using MYAS and EPSPAM data, we find that drought increases the migration gap, favoring rural adolescent boys over adolescent girls and increasing the gap in hours worked in agriculture. Finally, using DHS data, we also find that drought increases the gender gap in wage employment and self-employment participation. Together, these findings suggest that exposure to drought reduces the economic opportunities of rural adolescent girls compared to adolescent boys.

Third, dropping out of school and facing precarious economic conditions may cause rural adolescent girls to become economically dependent on men, either as husbands (early marriage) or sex partners. Our results show that exposure to drought heightens the risk of cohabitation and marriage among rural adolescent girls, as evidenced by MYAS and EPSPAM data analysis. Additionally, using DHS data, we find that exposure to drought increases the likelihood of resorting to transactional sex, a prevalent practice among Malagasy youths (Freedman et al., 2020).

Finally, since both early marriage/cohabitation and transactional sex correlate with early fertility, rural adolescent girls exposed to the adverse impacts of drought may start having children earlier than their non-exposed counterparts. Indeed, using DHS data, we find that experiencing drought during adolescence raises the likelihood of childbearing by up to 2 percentage points, and the result is statistically significant. The magnitude of this positive effect becomes stronger when estimated using the MYAS and EPSPAM data. Importantly, we demonstrate that dependence on rainfed agriculture for livelihood is the pathway for this fertility timing effect of drought. In particular, drought does not trigger adolescent fertility if it occurs in an urban center or when the adolescent girl resides with a non-agricultural family. Furthermore, irrigation annihilates the effect of drought on an adolescent girl's fertility timing.

As evidence suggests that women who experienced early childbearing also tend to have higher completed fertility (Trussell and Menken, 1978; Cohen et al., 2011), particularly in sub-Saharan Africa (Senderowitz and Paxman, 1985), adolescent girls exposed to drought may therefore end up having more children than their unexposed counterparts.

The finding that in rainfed agricultural areas, low demand for women's labor, exacerbated by drought, increases fertility rates offers concrete support for a key aspect of the Unified Growth Theory and reveals a significant implication: rainfed agricultural regions, frequently affected by climatic shocks and hindered by gender norms limiting women's employment opportunities, could emerge as major contributors to the delay of the demographic transition in sub-Saharan Africa. Therefore, addressing population growth effectively may require a focused approach for these areas. One strategy could be targeting adolescent girls in drought-prone, rainfed agricultural areas. These interventions may aim to decrease their likelihood of early fertility. This approach has shown success in developed countries, as indicated by studies on career and educational advancements for women (Goldin and Katz, 2000, 2002). By adopting such strategies, the demographic transition, which involves moving from high birth and death rates to lower ones, could become a more universally achievable goal.

This paper contributes to the general literature exploring barriers to fertility transition in developing countries (Schultz, 1985; Galor and Weil, 1996, 2000; Bloom et al., 2009; Galor, 2011; Jensen, 2012; Mookherjee et al., 2012; Heath and Mobarak, 2015; Do et al., 2016; Lambert and Rossi, 2016; Doepke and Tertilt, 2018; Rossi, 2019; Alam and Pörtner, 2018; Rossi and Godard, 2022; Canning et al., 2022; Okoye and Pongou, 2024; Dupas et al., 2023; Bloom et al., 2009). In sub-Saharan Africa in particular, differential fertility behaviors have been explained by differential exposure to colonial population policies (Canning et al., 2022), missionary activity and human capital promoting institutions (Okoye and Pongou, 2024), forced labor (Dupas et al., 2023), polygyny (Rossi and Godard, 2022), and information technology (Abbasi and Pongou, 2023) among others.

Doepke and Tertilt (2018) also study fertility in the larger context of developing countries. They use theoretical and empirical approaches to investigate the relationship between women's empowerment and fertility outcomes, exploring how differences in fertility preferences between men and women influence fertility rates. Their paper highlights that because men typically prefer more children than women, this gender gap can lead to conflicts within households about the number of children to have. Consequently, the paper points to low women's empowerment as a key determinant of high fertility in developing countries. They provide macro-level evidence, using data from various developing countries, to support their theoretical conclusion, showing a strong correlation between measures of women's empowerment and lower fertility rates.

Our paper departs from theirs in two important dimensions. First, we focus on micro-level evidence of factors that undermine a woman's bargaining power in relation to fertility decisions, highlighting women's low relative economic opportunities in rainfed agricultural areas as the main explanation for their low earning power compared to men. In doing so, our paper validates a key prediction of a preeminent growth theory (Galor and Weil, 1996; Galor, 2011). Second, we provide micro-level evidence on the critical age interval at which a woman's low bargaining power, as determined by her relative earning power, influences her completed fertility. Thus, our paper adds the gender gap in environmental vulnerabilities to the factors that undermine women's bargaining power in relation to fertility. This has significant implications for population growth and economic development in rainfed agricultural areas, such as sub-Saharan Africa.

To the best of our knowledge, the only other study that presents micro-level evidence consistent with the UGT hypothesis that an increase in a woman's relative earning power decreases her fertility is Schultz (1985).[2] Schultz (1985) studies the relationship between women's wages and fertility in the context of Sweden. Leveraging exogenous variations in the world prices for grains and animal products, he shows an increase in Swedish women's wages compared to men's decreased fertility. We complement Schultz (1985) in three ways. First, we test the UGT hypothesis in the context of rainfed agriculture, where drought provides exogenous variations in the gender economic opportunity gaps across space and time. Second, we are the first to uncover the age interval at which this hypothesis binds. Third, we outline the micro-founded complex mechanisms driving the age-specific effect of drought on completed fertility.

Our paper also highlights a key implication of climate change for unified growth models and the demographic transition (Galor and Weil, 1996, 2000; Galor, 2005a, 2011, 2022; Lagerlöf, 2003, 2006; Cervellati et al., 2023). While predictions from these models have been tested in different contexts (see, e.g., Bleakley and Lange (2009); Shiue (2017); Fernihough (2017); Becker et al. (2010); Okoye and Pongou (2024); Spolaore and Wacziarg (2013)), we are the first to consider their relevance in the context of climate change in a region characterized by high fertility and low human capital, which describe a post-Malthusian regime. We do so in two ways. First, we demonstrate that droughts have age-specific effects on completed fertility, with their positive effect being driven exclusively by exposure during adolescence. Second, we show that drought exacerbates the gender gap in economic opportunities in the context of rainfed agricultural regions, thus reducing the marginal price of a child among adolescent girls forced to drop out of

[2]We thank Oded Galor and David Weil for pointing this paper to us.

school due to drought. Therefore, our analysis has clear implications for policies likely to accelerate fertility decline in drought-prone agrarian economies.

The rest of this paper unfolds as follows. Section 2 describes the data used for our empirical analysis. Section 3 lays out our empirical strategy for estimating the effect of drought exposure on completed fertility and presents the results of this estimation. Section 4 discusses the methodology used to estimate the impact of drought on fertility timing among young women; it also presents the results and possible mechanisms through which drought affects fertility. Finally, concluding remarks in Section 5 closes the paper.

# 2 Social Context, Data and Measurement of Key Variables

This section describes the social context underlying our empirical study, the data, and the measurement of our variables of interest.

## 2.1 Gender Norms As A Source of Gender Gaps in Earning Power

Our empirical strategy relies on the assumption that in rainfed agricultural areas, drought combined with gender norms undermines women's earning prospects relative to men. The validity of this identification assumption draws from the evidence that in developing countries, gender norms—society's informal rules that prescribe acceptable and appropriate actions based on gender — confine rural women to rainfed agriculture as a source of livelihood while also constraining their innovation capacity. In so doing, they significantly influence the economic opportunities available to women and men in rainfed agricultural areas by placing more substantial restrictions on women, affecting their access to resources, mobility, and decision-making capabilities compared to men.

This subsection documents this evidence through a selective review of the relevant literature. The common denominator of the literature reviewed here is that gender norms play a significant role in perpetuating the gender gap in earning power. Our review highlights five mechanisms through which gender norms in developing countries limit women's earning power relative to men: (i) they place restrictions on women's social interactions and freedom of movement; (ii) they limit their control over household finances; (iii) they prescribe men as the family breadwinners; (iv) prescribe household chores and caregiving to family members (including children) as the primary responsibility of women; (v) promote harassment and violence towards non-complying women. Below, we review the evidence on these mechanisms.

Although our literature review documents gender norms' influence on the gender gap in earning power across the developing world at large, such influence is also very palpable in Madagascar, the setting of our empirical study. For example, Gezon (2002) finds evidence in rural areas of Madagascar that women's economic roles are shaped by gender norms that influence access to resources and decision-making power. In particular, although rural women are not necessarily confined to agriculture, many of them earn their living through remunerated sexual and domestic relations with men. Cole (2004) echoes this fact by revealing evidence in Tamatave, Madagascar, that young women often engage in transactional sex as a strategy to cope with a lack of access to rewarding economic activities, which reflects broader gender inequalities and the limited economic opportunities available to them.

#### 2.1.1 Women take care of children, and men provide for the family

In virtually all countries, the most deeply entrenched gender norm is that housework and child care are women's purview, compliance with which leaves women with fewer hours to work for pay (Quisumbing et al., 2007; Quisumbing and Pandolfelli, 2010). Compliance with this gender norm induces women to look for paid work that allows them flexible work hours and limited traveling to balance labor force participation with their household responsibilities. This, in turn, restricts women's access to lucrative economic opportunities and undermines their success at paid employment. In support of these facts, Delecourt and Fitzpatrick (2019) find evidence in Uganda that, among owner-managers of small drug stores, 38% of women had their small children with them at work at the time of unannounced visits by the research team. The corresponding number for men was 0%. Using a fixed effect regression model, Noonan (2001) finds evidence that women's compliance with their primary responsibility as caregivers to younger children and providers of unpaid labor reduces their wages in rural Madagascar. Fitawek et al. (2020) examine the impact of large-scale agribusiness investments in rural Madagascar and document find that household chores and caregiving to children constrained rural women's access to lucrative wage employment, limiting their earning power.

### 2.1.2 Gender norms constrain women's innovation in agriculture

Decisions about technology adoption in agriculture are tied to property rights over land and land tenure security. In rainfed agricultural areas where these technologies are most needed, gender norms significantly constrain rural women's ability to innovate in agriculture. They limit women's access to resources, decision-making capacities, mobility, and participation in innovation networks, ultimately impacting their ability to innovate and improve agricultural productivity. Fafchamps and Quisumbing (2005) find evidence of intra-household inequality favoring men in access to, or use of, agricultural land in Ethiopia. Quisumbing et al. (2015) find evidence in Africa and Asia that gender norms restrict women's participation in high-value agriculture, limiting their ability to accumulate and control assets. In a literature review, Quisumbing and Pandolfelli (2010) find evidence that these norms prohibit women's membership in Water User Associations due to a lack of secured land rights. Badstue et al. (2020) document evidence in Ethiopia that women often struggle to access and control agricultural resources such as land, water, and technology due to entrenched customary norms and gender-based violence that limit their innovation success. Lodin et al. (2019) find evidence in Kenya and Nigeria that gender norms restrict women's movements compared to men, limiting their access to agricultural services and participation in farmer groups, which are crucial for innovation. Bullock and Tegbaru (2019) also find evidence in Kenya that gender norms continue to define men as authorities and decision-makers in rural settings, limiting women's innovation capacity. Badstue et al. (2020) find evidence in Ethiopia that gender-based violence limits women's achievements in agricultural innovation. This literature confirms that gender norms significantly constrain rural women's ability to innovate in agriculture, contributing to the gender gap in earning power.

### 2.1.3 Women migrate for marriage and men for labor

In rural areas of sub-Saharan Africa, labor migration is common, with men migrating more often than women for labor-related reasons. Various socioeconomic and cultural factors influence this migration. Indeed, Camlin et al. (2019) find evidence in rural Kenya and Uganda that labor migration is more common among men than women, while women were more likely to travel for non-labor reasons. In Kenya, Agesa (2004) also finds that labor migration from rural to urban areas is predominantly male. Amirapu et al. (2022) find evidence in Bangladesh that traditional gender norms restrict women's independent migration for economic opportunities, leaving marriage as the only motive for women's migration. In rural Kenya, Crossland et al. (2021) also find that male out-migration outpaced women's. Finally, Hofmann (2014) finds evidence that patriarchal structures and gender ideologies in Madagascar constrain women's labor migration. Particularly, women from more traditional households are less likely to migrate than those from more egalitarian households. These research works confirm that in rural areas of developing countries, men migrate more often than women for labor due to traditional gender norms. This gendered migration pattern reflects expectations of men as breadwinners prevalent in these countries and reinforces male authority over women's migration decisions, limiting their economic opportunities and earning power.

### 2.1.4 Women either work in family farms or engage in low-pay self-employment

In many rural areas of developing countries, men's alternative to farm work includes access to lucrative self-employment, such as craft manufacturers and vendors, and non-farm salaried employment. By contrast, rural women's only alternative may be to access low-pay self-employment to balance their caregiving responsibility and paid work. In support of these facts, Ahmed and Sen (2018) find evidence in Bangladesh that gender norms restrict women's participation in non-farm salaried work. Adepoju and Osunsanmi (2018) find evidence in rural Nigeria that gender norms limit women's access to lucrative economic opportunities due to the requirement of long-distance traveling, which benefits men and not women. Egger et al. (2021) find evidence in rural Asia, Latin America, and sub-Saharan Africa of the persistence of a gender gap in off-farm employment. Wang and yuan Dong (2014) also find evidence in rural China that women's household responsibilities limit their participation in non-farm paid employment relative to men. Finally, Rakotomanana et al. (2021) show that traditional gender roles in Madagascar assign primary childcare responsibilities to women, limiting their ability to engage in non-farm salaried employment. Given these restrictions, poor rural adolescent girls who drop out of school are likely to become dependent on men for survival, which, in turn, may trigger early childbearing.

### 2.1.5 IPV as norm-enforcing mechanism

One may argue that women do not have to comply with gender norms that undermine their financial autonomy. However, the prevalence of harassment and violence, including in public spaces, may point to the existence of enforcement mechanisms to incentivize women's compliance with gender norms that constrain their earning prospects. Indeed, using Indian data, Krishnan et al. (2010) find that, for women, becoming employed is associated with experiencing more intimate partner violence (IPV), while ceasing employment reduces exposure to such violence. Vyas et al. (2015) find evidence in Tanzania that gender norms mediate the relationship between women's access to economic resources, e.g., employment or access to micro-credit, and their exposure to IPV. Where such norms subordinate women to men, engaging in paid employment is likely to expose a woman to IPV. Stöckl et al. (2021) corroborates this finding by documenting evidence that women's employment, particularly when they earned more than their partners, was associated with increased IPV in sub-Saharan Africa, where gender norms constraining women's economic empowerment are strong. It is also corroborated by Bhalotra et al. (2021), who find evidence that improvement in women's employment opportunities is associated with increased IPV in social environments where women have less access to divorce. Finally, Badstue et al. (2020) find evidence in Ethiopia that gender-based violence is a significant barrier to women's ability to innovate in agriculture. This body of research thus documents that gender norms significantly increase the risk of IPV in developing countries by perpetuating power imbalances and justifying violence to induce women's compliance. Therefore, in anticipation of IPV, rural women and adolescent girls may make choices that reduce their labor market earning prospects.

## 2.2 Data on Women

The setting of our empirical analysis is Madagascar, a large island on the south-eastern coast of Africa, with a poverty rate of nearly 80 percent at 1.90 PPP per day in 2012 (World Bank, 2016). In this African Island, agriculture is a source of livelihood for roughly 70 percent of the population (Minten and Barrett, 2008), cultivating less than 1.5 hectares per household (WFP and UNICEF, 2011) and being highly dependent on rainfed production. Over the years, it has become the site of frequent occurrences of extreme climatic events, such as cyclones, droughts, and floods, known to adversely affect agricultural production (World Bank, 2012). According to the World Bank, between 2005 and 2010, 93 percent of Malagasy households were affected by shocks, with climatic hazards accounting for most of them. In particular, weather shocks affected 83 percent of the rural population and 63 percent of the urban population in 2009-2010.

Rural households, most of which rank no higher than the second quintile of consumption distribution, responded to these shocks by further entrenching their dependence on rainfed agriculture, as their ability to transition into non-agricultural activities was weakened by a combination of poor transport infrastructure and limited business opportunities in the non-agricultural sector (World Bank, 2016). Interestingly, according to World Bank's estimates, in 2016, the average total fertility rate for the first two quintiles in the consumption distribution was 6.35 births per woman, which is nearly twice as high as the average total fertility rate of the top two quintiles (3.55 birth per woman). These facts make Madagascar an interesting setting for investigating the causal effect of agricultural droughts and, more in general, of income shocks on household fertility.

Our primary data on women's characteristics come from the 1997 and 2008 Madagascar Demographic and Health Surveys (DHS). DHS database contains detailed information on individual characteristics of women aged $15-49$. This includes information on their age at first birth and first marriage, their education level, their employment status, age group, marital status, birth history, their household characteristics (e.g., household size, number of children, etc.), as well as their area and region of residence. The main advantage of this dataset is the possibility of tracking the full fertility history, the relatively wide range of information, and the potential for getting a large sample size. Importantly, DHS data allows us to track when interviewed women migrated to the locality during the survey.

When studying women's completed fertility, we need to focus on women who have already completed their fertility to build our analysis sample. Therefore, we need a threshold age above which a woman is no longer expected to have children and below which she still is.

To uncover this threshold, we use the entire sample of women aged $15-49$ to compute the average number of children born to a woman for each age in that interval. Figure 2 represents this average number of children. This figure shows that the average number of children born to a woman increases with her age up to 43, after which it plateaus at around 6.4 children per woman. Therefore, to study the effect of drought on women's completed fertility, we exclude from our main sample all women who were 43 years old or younger at the time of the survey. In other words, our analysis sample for the main analysis (completed fertility) consists of rural women aged $44-49$, totaling $1,611$.

Of these women, 95 percent have had a child, with an average of 6.36 children per woman. Their mean age at first birth is 20.3 years old, and they attended an average of 3.35 years of schooling (Table 1, top panel). As discussed in the results section, our main findings reveal that droughts affect completed fertility only when they hit women at a young age ($15-19$ years old) but not later. For this reason, we only investigate the effect of drought on fertility timing (one of the mechanisms driving the main effect) on young women. Consistently with the main results, for the fertility timing analysis, we consider women aged between 16 and 21, that is, the age group of women who may have been hit by drought at $15-19$ and who may have consequently given birth one or two years after the exposure to drought (i.e., between 16 and 21). This selection gives a sample of $16,259$ for women residing in rural areas. Table 1, bottom panel, shows that among these women, 16 percent have had a child and were affected by drought.

## 2.3 Supplementary Data on Women

To conduct a robustness check on fertility timing and analyze potential mechanisms, we supplement the Madagascar DHS with longitudinal data from the two latest rounds of a survey that follows a cohort of young adults born in the late 1980s. They consist of the Madagascar Life Course Transition of Young Adults Survey (MLCTYAS) (2011–2012) and the Progression through School and Academic Performance in Madagascar Survey (EPSPAM 2004). These are follow-ups of a PASEC nationwide school-based survey of 2nd-grade primary school students conducted in 1998. In 2004, the sampling frame was adjusted in order to assure national representation; in particular, children who were out of school in 1998 were added to the sample.[3]

Both survey rounds contain comprehensive information on young women and their family members. In particular, the survey questionnaire includes modules on young women's education, labor, migration, health, fertility, and nutrition. In addition, there is also information on households' asset holdings, as well as on young women's children. The cohort-based sample also includes considerable retrospective data collected using recall techniques. For example, we know the exact month and year in which a young woman gave birth to a child and the exact month and year during which she migrated. In addition, this survey is complemented by a community survey of social and economic infrastructure and general information on key historical developments in the villages where young women lived in 2004. All these characteristics make this data extremely rich. We also rely on another data source, the 2001 Commune Census, which provides information on services, infrastructure, and agricultural production (among others) for all Malagasy communes.[4]

We build an 8-period panel of observations based on information about 572 young women living in rural areas of Madagascar (out of a total sample of 1,119 individuals) whose median age at the beginning of the period (2004) was 15 and at the end (2011) 22 years old. The youngest surveyed women were 14 in 2004, while the oldest 23 in 2011. Of

[3] Actually, no population census was conducted in Madagascar from 1993 to 2018. This implies that any survey conducted in the country in this period can be considered truly nationally representative (see Glick et al. (2011) and Glick et al. (2005) for more details on the sampling frame.

[4] *Recensement des Communes* 2001, http://www.ilo.cornell.edu/ilo/data.html.

these 572 rural young women, 146 left their community of origin between 2004 and 2011 to move to another Malagasy area – rural or urban. We define these women as internal migrants. In the period going from 2004 to 2011, the attrition rate represents roughly 10 percent of the sample.[5] Table 2 presents summary statistics for these young women. The average age at first cohabitation (with or without marriage) and the average age at first birth are 18 years for them. Fertility rates among them increase with age. Women aged 14 have, on average, 0.01 children, and women aged 23 have 0.95 children. At the beginning of the period (2004) 3 percent had a child and at the end (2011) 54 percent gave birth. Several women with children do not live with their partners. The percentage of such women drops with age, going from 70 per cent for young women aged 16 to 27 per cent for those aged 23. At the same time, cohabitation among young women is common even in the absence of a child: 40 percent of young women aged 14 to 17 already live with a partner, albeit without any child yet. This shows that in Madagascar, cohabitation at a young age is not uncommon, although not always related to pregnancy. Almost 17 percent of these women in our sample were enrolled in school in 2011, while 84 percent worked. Most of these working women are employed in family farms or businesses, with only 9.9 percent holding a salaried job, while 31 percent are own-account workers or employers. Looking at the economic sectors, most of these working women are employed in the agricultural sector (86 percent, or 298 women), where, on average, they spend 27 hours a week. On average, over the 2004-2011 period, about half of the young women in our sample are unemployed. Finally, 79 percent of sample women live in an agricultural household, *i.e.*, in a household that cultivated land between 2004 and 2011, or whose household head worked in the agricultural sector over the same period.

## 2.4 Fertility Measures

We are interested in two fertility outcomes: completed fertility (long run) and fertility timing (short run).

The main analysis sample of the effect of drought on completed fertility consists of

[5] Missing and re-interviewed cohort members are fairly similar with respect to any individual and household characteristics including gender, various crystallized intelligence scores, young women and parents' years of education, wealth, and area of residence.

individual observations of women aged 44 − 49 in the year of the survey. We showed above that this age group comprises women most likely to have completed their fertility. Therefore, we measure completed fertility as the number of children $N_{i,t,k,s} \geqslant 0$, born to a woman $i$ aged $t \in [44, 49]$ who was born in year $k$ and resides in grid cell $s$.

Our interest in the timing of fertility is related to our exploration of the age-specific effect of drought on completed fertility. Indeed, if drought affects the completed fertility of women in a given age group, it must be that it also affects their fertility timing. For the analysis of fertility timing, our dataset consists of individual observations on all women aged 15 to 49 at the year of the survey for DHS data and all cohort women for the longitudinal data. However, because of the focus age group of this analysis, with both data, we consider their fertility behavior only when they were aged 16 to 21. We construct an indicator function for fertility timing, which equals 1 if a woman gave birth to a child in year $t$ and zero otherwise.

## 2.5 Drought data and Measurement

Drought is a natural hazard that originates from a rainfall deficiency over an extended period, resulting in a water shortage for some activities, including rainfed agriculture (Wang et al., 2016). The focus of this study is agricultural drought—a negative rainfall shock that usually occurs on time scales of 1–4 weeks or longer and can have a direct impact on crop growth and yield.[6] Therefore, we want our measure of drought to capture low rainfall occurrences during a climatological wet season, which, in the context of Madagascar, is referred to as the rainy season—a period of time considered crucial for the development of crops.

### 2.5.1 Drought Data

To assess drought impacts, we use two distinct rainfall datasets. For the analysis using DHS data, we rely on the *Climatic Research Unit (CRU)* dataset, which provides a

[6] from the American Meteorological Society (AMS) – https://www2.ametsoc.org/ams/index.cfm/about-ams/ams-statements/statements-of-the-ams-in-force/drought/.

long-term rainfall series dating back to 1901. Based on weather station observations, this dataset is widely used in the literature (Dell et al., 2014). After matching this data with the Madagascar DHS 1997 and 2008, we obtained data for 201 rural grid cells (defined on grids of 0.5 latitude by 0.5 longitude).

For the analysis of the longitudinal data, we turn to the data from the *African Rainfall Climatology, version 2.0 (ARC2)*, of the *National Oceanic and Atmospheric Administration*.[7] This dataset, based on remote sensing satellite data, provides daily precipitation estimates from 1983 to 2011, with a spatial resolution of approximately 10 x 10 km. After matching this data with the MYAS and EPSPAM surveys, we obtained data for 54 satellite-based units (SBUs) in rural areas at baseline when we excluded migrants.[8]

### 2.5.2 Measuring Drought

In our study, drought is measured as a transitory negative rainfall shock. Specifically, our drought variable ($DROUGHT_{s,t}$) is equal to 1 if the standardized rainfall deviation in a given grid cell/SBU $s$ falls below the 20th percentile during year $t$, and 0 otherwise. Standardized rainfall deviation is calculated as the difference between rainfall in a given year and its historical mean within the grid cell/SBU over the agricultural season, normalized by its historical standard deviation. By adopting this approach, our measure of drought is localized and does not rely on comparisons of actual rainfall levels across different districts or grid cells/SBUs. The choice of the 20th percentile as the threshold for defining drought intensity is consistent with recommendations from the *American Meteorological Society* (Bergemann et al., 2015) and is widely used in the economics literature (Shah and Steinberg, 2017; Kaur, 2019). For completed fertility analysis, we measure drought exposure during a woman's age cohort ($DROUGHT_{s,A}$) as the total number of drought shocks experienced by the woman during her age cohort $A$.

[7] The reason why we do not use the CRU data in the analysis of the longitudinal data is that, as discussed in Marchetta et al. (2019), these data are of dubious quality between 2006 and 2009. This does not represent an issue for the same analysis using the DHS data because no women younger than 20 have been surveyed after 2005.

[8] If we include migrants, we end up with 143 SBUs, given that migrants move to different localities.

### 2.5.3 Timing of Drought, agricultural activities and fertility

As mentioned above, the focus of this paper is agricultural drought. In the developing world, one of the primary impacts of drought during the rainy season is crop failure. Aligning drought timing with Madagascar's crop calendar is crucial for our analysis. The country's main staples, rice and maize, have sowing seasons that begin in November and end in January for rice and December for maize. The rice growing season goes from February to March, a month later than the end of maize's growing season.[9] These seasons coincide with the rainy season when abundant rainfall is expected, making it an essential period for crop development. Therefore, our drought variable ($DROUGHT_{s,t}$) captures drought onset from November of year $t-1$ to April of year $t$, encompassing the critical period for crop growth.

Consistent with the main crops' calendar (which is expected to affect the timing and extent of crop failure), for the analysis of fertility timing, we assume that fertility in year $t$ is influenced by drought occurrences in years $t-1$ and/or $t-2$. This assumption accounts for drought's immediate and lagged effects on fertility. Specifically, we argue that couples anticipate or experience decreased agricultural productivity due to insufficient rainfall or a delayed onset of the rainy season, which may influence fertility decisions. Moreover, as women are often significantly involved in all agricultural activities (including selling crops), their time value after the rainy season decreases if drought negatively affects agricultural production.

This implies that to be associated with a drought episode in year $t-1$, childbirth must occur sometime between January and December of year $t$, as shown in Figure 3. This is an immediate effect of drought on household fertility. In addition to this immediate effect, we also consider a two-year lagged drought variable to account for the fact that pregnancy may take time to materialize for various reasons, including biology.[10]

[9] See FAO-GIEWS, 2022. *Country Briefs: Madagascar*, Reference date is 19 December 2022. Accessed online at `http://www.fao.org/giews/countrybrief/country.jsp?code=MDG`. Harvest timing for maize typically occurs in March and April, while for rice, it ranges from April to June.

[10] One might argue that using the month of birth to capture the fertility effect of drought would have been a better alternative to the year of birth considered in this study. However, our data show that the distribution of births after a one-year or two-year lagged drought is fairly constant across the year. Individuals' biologically related disparities in the onset of pregnancy are a possible explanation as to why there are no birth peaks around 9 months after the end of the drought.

# 3 Drought Exposure and Completed Fertility

The main objective of this paper is to test whether exposure to drought increases a woman's completed fertility. A key issue in the estimation of the effect of exposure to drought on completed fertility concerns the age at which such exposure matters to a woman's completed fertility. Our dataset consists of $1,611$ rural women aged $44-49$ in the year of the DHS survey (1997 or 2008). We track their exposure to agricultural drought at various stages throughout their lifecycle, distinguishing between five age groups denoted $A$. These age groups are: $15-19$, $20-24$, $25-29$, $30-34$, and $35-40$ years. In other words, $A \in \{15-19, 20-24, 25-29, 30-34, 35-40\}$.

## 3.1 Econometric Specifications

We estimate the following regression equation:

$$N_{i,a,k,s} = \sum_{A=1}^{5} \beta_{1,A} DROUGHT_{s,A} + \omega_1 \theta_a + \omega_2 \mu_k + \omega_3 \sigma_s + \varepsilon_{i,a,k,s} \quad (1)$$

where $N_{i,a,k,s}$ measures the total number of children born to a woman $i$ aged $a$ born in year $k$ and residing in grid cell $s$; $\omega_1$, $\omega_2$, and $\omega_3$ denote the age, year of birth, and grid cell fixed effects respectively. Based on the 1997 and 2008 Madagascar DHS, the average number of children born to women aged $44-49$ and living in rural areas is 6.4 (see Table 1). In addition, following Conley (1999) and Hsiang et al. (2011), we correct standard errors by allowing for both spatial correlation across the grid cells within a radius of 50 km (the median distance across grid cells) and infinite serial correlation.

Births induced by drought in a given cohort may not imply a permanent increase in fertility if a decrease in older cohorts later compensates for these births. In other words, drought might cause a temporary shift in fertility patterns without impacting the overall number of children by the end of women's reproductive years. This argument is similar to those discussed by Deschenes and Moretti (2009), who study the effect of extreme temperatures on social outcomes, and Hsiang and Jina (2014), who examine the effect of cyclones on economic growth. Specification (1) addresses this issue as it includes drought events for all age cohorts. If years following a drought occurrence have a fertility response that is opposite in sign to the response in younger age cohorts, this indicates the presence of temporal displacement or harvesting (Hsiang, 2016). Therefore, there is no harvesting if years following the drought have fertility responses that are of identical signs to that of the fertility response of drought that occurred in earlier ages or if they have fertility responses that are not statistically significant. Therefore, $\sum_{A=1}^{5} \beta_{1,A}$ gives the dynamic causal effect of drought, which corresponds to the sum of the coefficients of drought exposure for any age cohort.

Migration is another aspect of concern. DHS data allow identification of whether individuals have always resided in their current area of residence and, if not, the precise timing of their in-migration. However, since the DHS does not offer precise details on where a woman lived before migrating, we cannot accurately connect her to any climate shocks experienced before arriving there. As a result, we also present the findings of our baseline specification using a sample that excludes migrants.

## 3.2 Estimation Results

In this section, we report our main results on the effect of drought on women's completed fertility and explore their robustness to different specifications.

Column 1 of Table 3 reports the estimation results for our baseline specification, which does not control for the tendency of drought episodes to be clustered in space nor for the presence of migrants in the sample. We find that the age at which a woman is exposed to drought matters to the effect such exposure has on her completed fertility later in life. On the one hand, exposure to drought for an additional year during adolescence ($15-19$) increases a woman's completed fertility by 0.448 children, and the effect is statistically significant. On the other hand, exposure to drought post-adolescence has no statistically significant effect on a woman's completed fertility. When we exclude migrants from our sample and account for spatial and infinite serial correlation (see column 4 of Table 3), the positive causal effect of drought on fertility for women exposed to it during adolescence grows slightly (0.485) while also remaining statistically significant. However, there is no statistically significant effect for women exposed to drought post-adolescence, even after correcting for these challenges to identification.

Our results reveal that adolescence is the critical period in a woman's lifecycle during which drought exposure matters to her completed fertility. However, to identify public actions likely to protect adolescent girls from the adverse effects of drought exposure, it is important to first understand why adolescent girls exposed to drought have higher fertility rates than those unexposed at that age. This issue is the focus of the next section.

# 4 Mechanisms

In this section, we delve into the potential mechanism driving drought's impact on the completed fertility of women who experienced it during adolescence. This mechanism unfolds in four distinct steps outlined below.

Firstly, drought serves as an income shock, leading parents in affected households to pull their children out of school. This withdrawal disproportionately impacts girls, worsening the existing gender gap in education. Secondly, rural adolescent girls who discontinue schooling often face limited economic opportunities due to prevailing gender norms that favor men as primary breadwinners. These young girls seek economic avenues but encounter many challenges. Due to drought, agricultural labor is less productive, and the demand for work is lower, especially for women, as evidenced by the disparity in hours worked in the sector between genders. Opportunities for women in wage and self-employment, already scarce in the study context, diminish further: one common livelihood strategy for women is crop selling, but the reduced crop yields limit this activity. Young women also face increasing competition with men in non-agricultural sectors. Additionally, reduced resources available for financing migration result in fewer migration opportunities for women than men, who may be favored in migration selection in a liquidity constraint situation. Thirdly, the decline in livelihood opportunities for women pushes them towards increased dependence on men through early marriage and transactional sex, as indicated by the reduced age at marriage and by the rise in the number of sexual partners. Finally, early marriage and transactional sex, in turn, cause the anticipation of fertility, which ultimately leads to higher completed fertility rates. We test this four-step mechanism using two different datasets.

### 4.1 Drought Increases Girls' School Dropout

Droughts are negative income shocks when they occur in an agrarian economy dependent on rainfall for crop performance (Dinkelman, 2017). For agricultural households, the ensuing economic hardship can induce parents to pull their children out of school due to economic struggle. We test this hypothesis using longitudinal data from the Madagascar Young Adult Survey (MYAS) and EPSPAM by estimating the following linear probability model (LPM):

$$SE_{i,a,s,t} = \sum_{l=0}^{1} \beta_{1,l} DROUGHT_{s,t-l} + \gamma_1 X_{i,t} + \gamma_2 X_i + \omega_1 \theta_a + \omega_2 \mu_t + \omega_3 \sigma_s + \varepsilon_{i,t} \qquad (2)$$

where $SE_{i,a,s,t}$ measures the school enrolment of a girl aged $a$ in year $t$. $X_{i,t}$ include individual, household, and community-level time-variant characteristics. $X_i$ includes time-invariant individual-level characteristics such as parents' education and the ethnicity group.[11] The term $\omega_1$ captures the young woman's age effect, while the terms $\omega_2$ and $\omega_3$ capture the temporal and the SBU fixed effects, respectively. In this specification, as well as in the subsequent tests for the described mechanism, we examine the impact of a drought occurring in year $t$ to observe the immediate effect ($l = 0$), and a drought occurring in year $t-1$ to observe the lagged effect ($l = 1$).

Column (1) of Table 4 presents the test result. We find that drought indeed reduces adolescent girls' school enrolment by nearly 7 percentage points, and the result is statistically significant. This result raises the issue of what would happen to these rural

[11] More specifically, $X_{i,t}$ includes the number of brothers and sisters, if the father (mother) is ill or dead, if the father (mother) is currently working, if the cohort member lives in the original household surveyed in 2004, the number of health centers in the village and the number of primary/secondary schools in the village. $X_i$ includes the entry age at school, ethnicity, the father's education level, the mother's education level, the household asset in 2004, a dummy indicating if the household cultivated land in 2004, if the village has access to a paved road and to irrigation in 2001, and dummies for climatic zones.

adolescent girls forced to drop out of school. We will explore this issue next.

## 4.2 Drought reduces girls' economic Opportunities

In many rural communities of the developing world, women face gender-based constraints to their livelihood choice, including restrictions on the ownership of productive assets (Quisumbing et al., 2007; Doss, 2018), the creation of social costs for women who migrate (Agesa and Agesa, 1999; Evertsen and van der Geest, 2020), and the prescription of unpaid care labor as their primary responsibility (Rao, 2018; Islam and Sharma, 2021). In this context, rural adolescent girls forced to drop out of school due to drought may struggle for economic survival. We test this in three different ways, as outlined below.

### 4.2.1 Drought reduces adolescent girls' labor supply in farming

In a context where farming is the main occupation for women, but gender norms restrict their access to assets likely to increase labor productivity in farming, as the literature finds (Gray, 1993; Quisumbing et al., 2004; Doss et al., 2014; Ncube et al., 2018), then drought may reduce female labor supply in farming. We test this using longitudinal data. In so doing, we regress the number of worked hours in the agricultural sector over the last seven days preceding the interview ($H_{i,s}$) by young females and males separately as follows:

$$H_{i,s} = \beta_1 DROUGHT_{s,2011} + \beta_2 DROUGHT_{s,2010} + \gamma X_i + \omega \sigma_s + \varepsilon_i. \quad (3)$$

This regression was run only on people who reported a positive number of hours in the agricultural sector. MYAS data provide information on the number of worked hours for the last year of the survey only (i.e., 2011).[12] Nevertheless, given the large variability of drought episodes across the localities, we can still identify the causal effect of drought on our outcome of interest. Additionally, given that survey respondents were interviewed between December 2011 and January 2012, our outcome in Eq. 3 is compa-

[12]Out of 402 (401) total women (men) in rural areas, 300 (294) reported being working in the agriculture sector as their primary occupation; only 3 (none) of them reported missing hours' values.

rable across the observations and falls precisely during the agricultural season (hence, susceptible to being affected by drought).[13] Results of this regression are presented in column 4 of Table 4. We find that drought in the current year reduces a young woman's number of hours worked in farming. When running the same model on young men (Table 4, column 5), we observe that the number of hours worked in farming increases for young men. The Wald test rejects the null hypothesis of equality between the two estimated parameters, implying that the difference between these effects is statistically significant. This gender-based heterogeneity of the effect of drought on hours worked reflects social norms that restrict women's access to productive assets, thus hindering the effectiveness of their resilience in farming compared to young men.

#### 4.2.2 Drought reduces adolescent girls' opportunities in wage work and self-employment

In the rural areas of developing countries, many women rely on post-harvest activities like selling transformed or non-transformed crops for income. However, the loss of crop yield due to drought reduces either the time a woman allocates to this activity (if self-employed) or the wage the wage she receives (if wage-employed). Furthermore, in rainfed agricultural areas where traditional gender norms preclude competition between men and women in the pursuit of economic opportunities (Afridi et al., 2022), the drop in agricultural productivity reduces young women's earning power, as they are restricted from competing with men in more lucrative non-agricultural sectors, making it even harder for them to find alternative sources of income.

We test this channel using the 1997 and 2008 DHS data, which provide us information on whether the individual was engaged in wage or self-employment works in the last 12 months, as follows:

$$ES_{i,s,t} = \beta DROUGHT_{s,t-1} + \gamma X_i + \omega\theta_a + \delta DHS_{2008} + \varepsilon_{i,t} \tag{4}$$

[13] Vector $X_i$ in equation 3 includes the following variables: if a woman was at school in 2010, highest grade, assets in 2004, if the father (mother) was ill or died in 2011, ethnicity, father's education level, mother's education level if the village has access to a paved road and to an irrigation system (in 2001), the number of health centers in the village, climatic zones.

where $X_i$ represents individuals' level of education. Given that we measure participation in wage and self-employment ($ES_{i,s,t}$) over the past 12 months, we can only observe the impact of drought in the preceding year. Therefore, it would be illogical to examine the effect of drought in the current year on labor participation in the months leading up to the drought. Unfortunately, the 1997 DHS does not offer the same information for men; the 2008 DHS supplies this information, but only to one man picked randomly in the household. Therefore, we used the 1997 and 2008 DHS for women but only the 2008 for men.

Columns 6 and 7 of Table 4 indicate that women reduce their participation in wage and self-employment following a drought, whereas this trend is not observed among men. In addition, the drought coefficients for women and men are statistically different, so we can conclude drought reduces women's access to economic opportunities relative to men, undermining their relative earning power.

#### 4.2.3 Drought reduces rural out-migration opportunities for girls

After experiencing a productivity shock such as drought, labor migration may offer young women an option for earning more. However, if gender norms restrict women's labor migration compared to men, as the literature finds (Agesa and Agesa, 1999; Lundgren et al., 2018; Evertsen and van der Geest, 2020), adolescent girls' school dropout may face a drop in their relative earning power due to the norm-enforced gender gap in labor migration.

We test this using the MYAS and EPSPAM data by estimating an LPM similar to Eq. 2 where the outcome variable is a binary variable equal to 1 if an individual $i$, aged 15-19, residing in SBUs $s$ migrated at time $t$, and 0 otherwise. From the year after the migration event, we withdraw the observation from the sample. In so doing, we estimate the effect of drought on the likelihood of migration separately among young males and females aged $15-19$ and use Wald's test to assess the null hypothesis that the difference between the two estimated parameters is equal to zero.

Table 4, columns 2 and 3, reports the result of this estimation. We find that drought the previous year reduces female migration by 21.2 percentage points but has no statistically significant effect on male migration. Wald's test subsequently confirms that the difference between the two estimated parameters is statistically significant, implying that drought increases the gender gap in labor migration favoring young males over young females.

In summary, the findings above provide suggestive evidence that drought decreases the economic opportunities for young women compared to young men in rural rainfed agricultural areas. In such a context, adolescent girls forced to drop out of school due to drought would experience economic struggle compared to their male counterparts. Together, these findings thus imply that in rainfed agricultural areas where gender norms restrict women's pursuit of economic opportunities, drought creates the conditions underlying the validity of the UGT hypothesis: a loss in women's relative earning power.

### 4.3 Exposure to Drought and Adolescent Girls' Economic Dependence on Men

We established above that adolescent girls forced to drop out of school face a struggle to survive relative to their male counterparts. This precarious situation, in turn, may lead these girls to become dependent on men's resources for survival, for example, in the form of early marriage or transactional sex—a practice that is becoming increasingly common among young girls in Madagascar as a means to escape poverty (Freedman et al., 2020).

For cohabitation,[14] we estimate a LPM similar to Eq. 2 where the outcome is an indicator function equal to 1 if a woman $i$, aged 15-19, residing in SBUs $s$ entered a cohabitation relationship with her partner at time $t$, and 0 otherwise. From the year after the cohabitation event, the woman is withdrawn from the sample. We test this hypothesis using the MYAS's and EPSPAM's longitudinal data.

To study the occurrence of transactional sex, we use cross-sectional data from the DHS 1997 survey, which asked all women aged 15-49 about the number of sex partners

[14] We are interested in the formation of couples, regardless of whether the woman is married through a civil or traditional marriage, which is very common in the country, or simply in a *union libre*.

they had in the 12 months prior to the survey. We hypothesize that in a context like rural Madagascar, where social norms advocate sexual abstinence until marriage (Rakotoniana et al., 2014; Freedman et al., 2021), especially for girls, engaging in multiple sexual partnerships may indicate the exchange of sex for money.

We test this by estimating the following specification for women aged 15-19:

$$SP_{i,s} = \sum_{l=0}^{1} \beta_{1,l} DROUGHT_{s,1997-l} + \gamma_1 X_i + \omega_1 \theta_a + \varepsilon_i, \tag{5}$$

where $SP_{i,s}$ measures the number of sex partners a woman aged 15-19 had during the 12 months before the survey, $X_i$ represents individuals' level of education Table 4 shows that a drought that occurred one year before the survey has a statistically significant and positive effect on early marriage among adolescent girls and the number of sex partners these girls had during the previous 12 months. These results suggest that in the context where gender norms impose constraints on women's economic livelihood choices, being exposed to drought makes poor adolescent girls dependent on men either as husbands (early marriage) or sex partners for economic survival.

### 4.4 Exposure to Drought and Fertility among Adolescent Girls

Having shown that drought increases rural adolescent girls' economic dependence on men, either as husbands or sexual partners, we now examine the impact of this dependence on their fertility. Cohabitation and multiple sexual partnerships may lead to earlier childbearing among drought-exposed girls compared to their non-exposed peers. To test this, we estimate the effect of drought exposure on the likelihood of early childbearing using both DHS and longitudinal data.

Fertility timing is the outcome variable of interest, which we denote as $CB_{i,s,t}$. It is an indicator function equal to 1 if a young woman $i$ residing in grid cell/SBU $s$ gave birth to a child at time $t$, and 0 otherwise. Our baseline specification for the estimation of the effect of drought on fertility timing is a linear probability model (LPM) with fixed effects at the grid cell/SBU level.

Since we are interested in the effects of droughts experienced during adolescence, we focus on young women aged 16 to 21 years old. This age window is consistent with the ages of the individuals used for the previous mechanisms (15-19) and accounts for the possibility that the effect of drought can materialize into a higher likelihood of fertility one or two years after (hence, up to 21 years old if the last age being affected in this group is 19). We first estimate this model on the sample of 16,259 women interviewed in the 1997 and 2008 DHS. Considering the longitudinal structure of our data, we end with having 85,663 observations-year. We estimate the following regression equation:

$$CB_{i,s,t} = \sum_{l=1}^{2} \beta_{1,l} DROUGHT_{s,t-l} + \omega_1\theta_a + \omega_2\mu_k + \omega_3\sigma_s + \delta DHS_{2008} + \varepsilon_{i,t}. \tag{6}$$

Standard errors are clustered on grid cell units to account for the possible correlation of droughts across grid cells. As a robustness check, we follow Conley (1999) and Hsiang et al. (2011) by correcting standard errors to account for spatial correlation across grid cells within a radius of 50 km as well as infinite serial correlation.

Table 5, columns 1 and 2, indicate that drought in year $t-2$ increases a young woman's probability of childbearing during adolescence by 0.10 percentage points. Upon re-estimating the same equation and replacing grid cell fixed effects with individual fixed effects, we obtain a similar result (column 3).

### 4.4.1 Challenges to Identification

Various concerns can arise when analyzing women's fertility timing during adolescence. First, there is the well-known "recall bias" problem. Indeed, this problem is more likely to occur when the events lapse three decades or more, as in our case. To minimize this identification challenge, we re-estimate Eq. (6) using a younger cohort of women – aged between 16 and 26 years old at the time of the survey – to minimize the recall bias. The findings (column 4) reveal that drought in year $t-2$ raises a young woman's likelihood of childbearing during adolescence by 0.20 percentage points.

In section 3, we examined completed fertility using a sample of women aged 43 to 49 at the time of the survey. While fertility decision dynamics may change over time, observing a positive effect of drought on fertility timing in younger women may not represent the experiences of older women at the survey time. Therefore, we re-estimated Eq. (6) using the same sample for the completed fertility analysis, i.e., women aged 43 to 49 at the time of the survey. The results, presented in column 5, still show a positive impact of drought on fertility. However, this time, they suggest that drought occurring in year $t-1$ increases the probability of childbearing during adolescence by 0.29 percentage points. It is worth noting that older women may find it challenging to recall the exact timing of childbearing, which could explain the differences in results compared to those presented earlier.

Finally, as indicated in Section 3, some women reported they have not always resided in their current area of residence. Consequently, we cannot be certain of matching them with the precise climate shock they experienced during adolescence. Therefore, we re-estimated Eq. (6) by excluding these women for the years before they relocated to their current areas. The results of this estimation are shown in column 6 and are consistent with those of the baseline analysis.

### 4.4.2 Timing of fertility using longitudinal data

We are able to analyze women's fertility timing during adolescence using longitudinal data as well. We believe it is interesting to do so for several reasons. First, as robustness, testing the same relationship using a different data source increases the validity of our results. Second, because the longitudinal data allow for a richer specification. Indeed, it is important to consider the individual heterogeneity that may be correlated with drought. For example, the resilience ability of an uneducated, unmarried, poor young woman to drought may differ from that of her more educated, married, or wealthier counterpart in a context where agricultural work is the only paid employment opportunity for women. Differences in resilience ability are also likely between women with access to irrigation, decent health, or transport infrastructure and those without access to these amenities. To address these sources of heterogeneity, thanks to the richness of the longitudinal data, we can add individual, household, and village time-varying and time-invariant characteristics of a young woman to the baseline equation, which is then modified as follows:

$$CB_{i,s,t} = \sum_{l=1}^{2} \beta_{1,l} DROUGHT_{s,t-l} + \gamma_1 X_{i,t} + \gamma_2 X_i + \omega_1 \theta_a + \omega_2 \mu_t + \omega_3 \sigma_s + \varepsilon_{i,t}, \quad (7)$$

where the time-variant term $X_{i,t}$ includes a woman's education level, health status, and parents' education levels and whether they died. The time-invariant term $X_i$ includes a woman's ethnic group, her family of origin's level of asset holdings, as well as various community-level variables. Using data from the 2001 Commune Census, we also include an indicator function equal to 1 if there are irrigation facilities in the commune (defined as if there are irrigated rice fields by a dam or a pumping station) and 0 otherwise. Including this variable as part of our empirical strategy for identifying the causal effect of drought can be justified because, in communes where the practice of irrigated agriculture is more widespread, agricultural TFP is likely to be less responsive to drought. We also include the number of vaccination campaigns and the number of health centers in a village, as these may influence women's reproductive health—a determinant of her fertility outcome. The explanatory variables are listed in the notes of Table 6, and their summary statistics are reported in Table 2.

Table 6 reports the results obtained using longitudinal data. Overall, switching to the longitudinal dataset does not alter our results qualitatively. Instead, the magnitude of the positive effect of drought on adolescent girls' probability of childbearing increases significantly.

Column 1 of Table 6 reports the results based on the whole sample of young women in the longitudinal survey (*i.e.*, young women aged $14-23$). We find that drought (in year $t-2$) increases the probability that an adolescent girl bears a child roughly by 7 percentage points. This result is statistically significant at the 10 percent level.

These results are obtained from a sample that includes women who migrated from the rural areas where they lived during the first round of the survey (i.e., in 2004) to urban areas or other rural areas. Their inclusion in the sample is likely to underestimate the effect of drought on adolescent girls' probability of childbearing. Indeed, if young women respond to agricultural droughts by leaving rural areas, our estimates are likely biased, as these migrants are less likely to depend on rainfed agriculture for livelihood, especially when they migrate to urban centers with relatively more employment opportunities. In columns 2-4, we thus exclude observations from the year they out-migrated and find that, on average, this increases the magnitude of the effect of drought on adolescent girls' probability of childbearing. When including this rich set of controls (column 3), the two-year lagged drought increases the probability of having a new birth by 10 percentage points.

Finally, in column 4 of Table 6, we demonstrate that the results remain consistent when we replace the SBU fixed effects with individual fixed effects in equation 7, thereby addressing potential unobserved heterogeneity at the individual level (e.g., perceptions of risks related to weather shocks, biological factors affecting fertility, or levels of education). Our results are robust to any potential time-invariant individual unobserved heterogeneity.

These empirical tests provide compelling evidence that droughts have a causal effect on adolescent girls' childbearing in rural areas dependent on rainfed agriculture. Our finding that drought increases completed fertility among women exposed to it during adolescence thus can be explained by the fact that early childbearing increases completed fertility (Morgan and Rindfuss, 1999; Cohen et al., 2011; Guzzo and Hayford, 2011).

# 5 Dependence on Rainfed Agriculture and Drought's Fertility Effect

We established in the main text that in rural communities directly dependent on rainfed agriculture, drought increases completed fertility among women exposed to it during their adolescent years, and this can be explained by its effect on the timing of fertility. However, one may argue that dependence on rainfed agriculture is not necessarily the source of mechanisms driving this fertility effect of drought. If so, then one would expect the fertility effect of drought to occur irrespective of (i) a household's primary sector of employment and (ii) whether a household lives in urban or rural areas. (iii) One would also expect this effect to be obtained whether or not farmers have access to irrigation. Using data on young women from the Madagascar Young Adult Survey and EPSPAM, we test these three hypotheses in what follows.

### 5.1 Agricultural households vs. non-agricultural households

Suppose that driving drought's fertility effect also operates for households involved in non-agricultural work. One would expect both agricultural and non-agricultural households to experience these effects—not just the former. We test this hypothesis by partitioning our results by the household's primary sector of employment (agriculture vs. non-agriculture).

We use the regression specifications in Eq. (7) to estimate the effect of drought on adolescent girls' childbearing probabilities by type of household (agricultural vs. non-agricultural). We define a non-agricultural household as one in which none of the members cultivated any land between 2004 and 2011, and neither the young women surveyed nor their fathers reported agriculture as their primary sector of work. According to this definition, households do not change from agricultural to non-agricultural activities, and vice versa, during the survey period. This implies that assignment to a given household type (agricultural or non-agricultural) is not affected by drought during that entire period.

Table 7 reports the results of our estimations in Columns (1) and (2). We find that drought that occurred a year or two previously increases the probability of childbearing among adolescent girls from agricultural households (see column 1) but has no effect on the childbearing probabilities of those from non-agricultural families (see column 2). This result implies that adolescent girls living in non-agricultural households are spared the positive fertility effect of drought, whereas their counterparts living in agricultural households bear the brunt of it.

### 5.2 Rainy season vs. non-rainy season

Suppose next that the mechanisms driving the fertility effects of drought also concern urban households and not only rural households. One would expect the drought to have a qualitatively similar effect on households living in urban and rural areas.

Column 3 of Table 7 reports the results of this test and shows that the coefficient of drought when urban households are considered is not statistically significant. These test results validate our hypothesis that dependence on agriculture as a source of livelihood is the source of mechanisms underlying the fertility effects of drought.

### 5.3 Rainfed vs. irrigated agriculture

Finally, suppose that rainfed agriculture is not the only source of the mechanisms driving the positive fertility effect of drought. One would expect irrigation to have no influence on this effect. Here, we test whether the presence of irrigation facilities mitigates the effect of drought on adolescent girls' childbearing. For this test, we add to Eq. (7) an interaction term between the irrigation variable, $IRRIG_c$, and the drought variable, $DROUGHT_{s,t-l}$, as a covariate. The econometric specification for this test thus is written as follows:

$$\begin{aligned} CB_{i,s,c,t} &= \sum_{l=1}^{2} \beta_{1,l} DROUGHT_{s,t-l} + \sum_{l=1}^{2} \beta_{2,l} DROUGHT_{s,t-l} \times IRRIG_c \\ &\quad + \gamma_0 Prov \times Year + \gamma_1 X_{i,t} + \gamma_2 X_i + \omega_1 \theta_{i,t} + \mu_s + \sigma_t + \varepsilon_{i,t} \end{aligned} \tag{8}$$

where $IRRIG_c$ is an indicator function equal to 1 if commune $c$ has irrigation facilities, and 0 otherwise, and $\gamma$ captures a province's time trend. One might argue that irrigation is endogenous as being close to a dam or pumping station is not random. However, this variable comes from the commune data set and was collected in 2001, so before the sampled young women had children and drought occurred; hence, our individual data set is exogenous to the irrigation variable. Furthermore, since the development of irrigation facilities may be correlated with other variables that can also mitigate the effect of drought, we control for the presence of credit institutions and local markets, in addition to the fixed effects at the SBU level (which measure time-invariant development level across SBUs). Furthermore, we assume that all households living in the same community are equally affected by the presence of irrigation. The endogeneity would then be across communities and not across households within the same community. Henceforth, we argue that our irrigation variable is plausibly exogenous, given our controls.

Regression results are reported in column 4 of Table 7. We find that the presence of irrigation facilities mitigates the positive effect of drought on adolescent girls' childbearing. The results of these three separate tests indicate that household dependence on rainfed agriculture for livelihood is the source of the mechanisms underlying the positive fertility effect of drought. We explore these mechanisms next.

# 6 Conclusion

This study tests a key premise of the unified growth theory: that a significant gender gap in earning power increases completed fertility. We examine this hypothesis in rainfed agricultural areas, where droughts disproportionately reduce women's economic opportunities compared to men's due to gender norms. By exploiting exogenous variations in rainfall deficits across time and space at the grid-cell level and controlling for grid and cohort fixed effects and the spatial correlation of these deficits, our analysis reveals an age-specific impact of drought on women's completed fertility. Specifically, drought exposure during adolescence increases fertility rates exclusively within this demographic. We attribute this effect to several drought-induced conditions: increased school dropout rates among rural adolescent girls, reduced female labor migration, and local labor opportunities. These drought-induced effects, reflecting the operation of traditional gender norms, in turn, raise the risks of early marriage and transactional sex among these rural girls, particularly those living in agricultural households without access to irrigation. Thus, our paper primarily demonstrates that there is a critical age window during which the hypothesis of the unified growth theory binds.

The policy implications of our findings are significant. Firstly, the fact that drought's influence on fertility is confined to adolescent girls underscores the necessity of targeted public interventions toward this vulnerable group, especially under the accelerating pressures of climate change. Secondly, as climate change is likely to increase the frequency of extreme weather events like droughts, without proactive measures, these phenomena could perpetuate and even exacerbate the gender economic opportunity gap in rainfed agricultural regions. This, in turn, could exacerbate gender inequality and delay demographic transitions in drought-prone agrarian economies. Given the relentless progression of climate change, it is crucial for public policies in these regions to prioritize employment opportunities for adolescent girls and women. If unaddressed, the slow pace of fertility transition—which is theorized to be a catalyst for sustained economic growth—could significantly impede economic development in the coming years, as noted in key studies by Galor and Weil (1999, 2000) and Galor (2005b).

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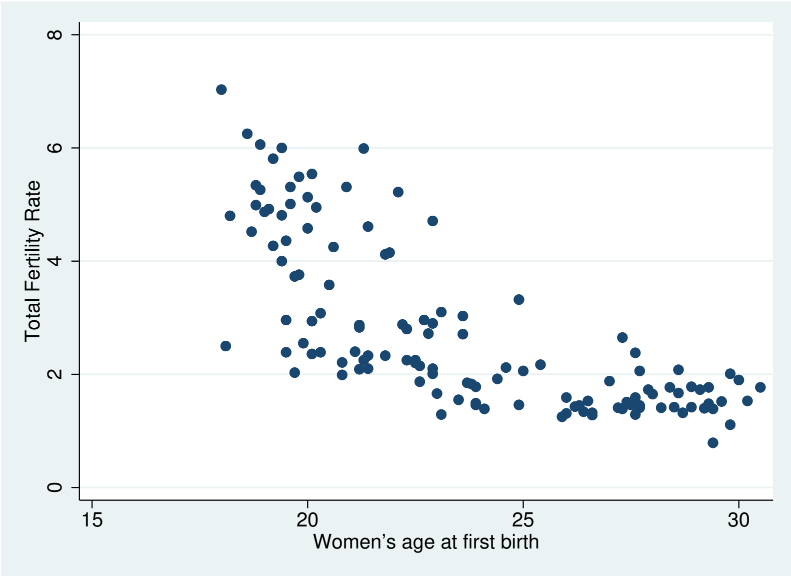
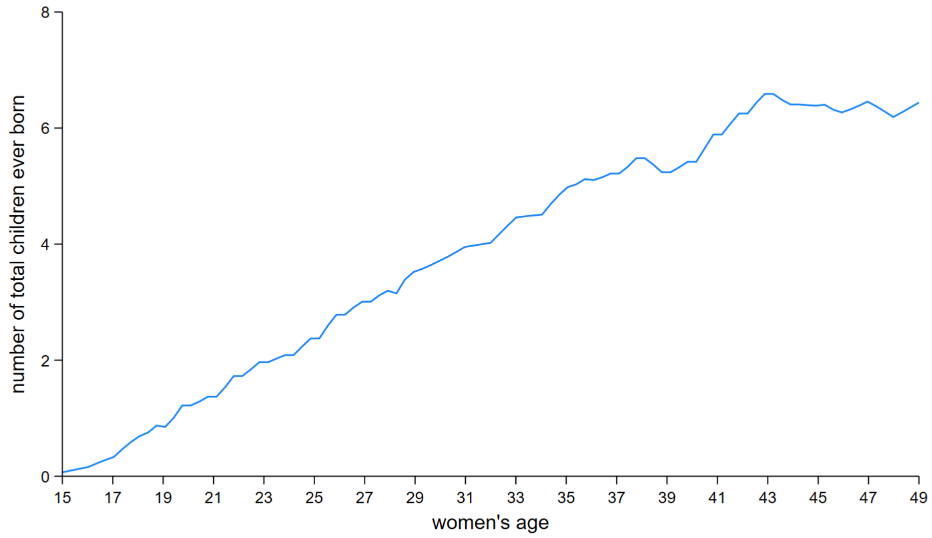
# Figures

**Figure 1:** ***Relationship between women's age at first birth and total fertility rate***



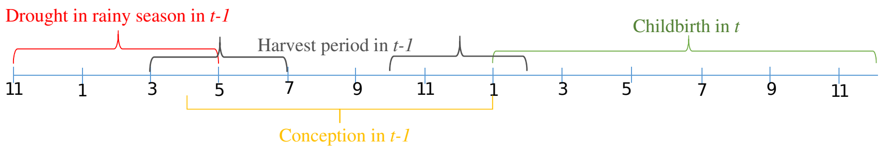

*Source*: Authors' elaboration from the CIA World Factbook. *Notes*: Data are from 126 countries around the world in 2013. The *Spearman's rho* is -0.74. A simple quadratic correlation OLS model that regresses the total fertility rate on the age at first birth (and its quadratic term) shows an R2 of 0.64.

**Figure 2:** ***Total number of children ever born by women's age, rural areas***




*Source*: Authors' elaboration from 1997 and 2008 Madagascar DHS.

**Figure 3:** ***Timing of key variables***




*Source:* Authors'elaboration.

# Tables

**Table 1:** ***Descriptive Statistics of key variables, women in rural areas (based on DHS data)***

| **Women 44-49 years old (sample used in the completed fertility analysis)** | | | |
|---|---|---|---|
| | Obs. | Mean | SD |
| Proportion of mothers | 1,611 | 0.95 | 0.23 |
| Mean number of children | 1,611 | 6.36 | 3.57 |
| Mean age at first birth | 1,521 | 20.29 | 4.96 |
| Mean years of schooling | 1,611 | 3.35 | 5.20 |
| *Total number of droughts experienced at:* | | | |
| 15-19 | 1,611 | 0.95 | 0.83 |
| 20-24 | 1,611 | 0.52 | 0.86 |
| 25-29 | 1,611 | 1.07 | 0.85 |
| 30-34 | 1,611 | 1.06 | 0.89 |
| 35-40 | 1,611 | 1.16 | 0.72 |
| **Women 16-21 years old (sample used in the timing of fertility analysis)** | | | |
| Had a child | 16,259 | 0.16 | 0.17 |
| Affected by 1-lag drought | 16,259 | 0.16 | 0.17 |
| Affected by 2-lag drought | 16,259 | 0.16 | 0.17 |
| Year of birth | 16,259 | 1976 | 10.50 |
| Age | 16,259 | 18.14 | 0.73 |

*Source*: Authors' elaboration from the 1997 and 2008 Madagascar Demographic and Health Surveys.

*Notes*: Droughts variables are constructed from the CRU series. Estimations are weighted by sampling weights. 'Number of sex partners in the last 12 months' is estimated using DHS 1997 (as DHS 2008 does not provide that info) on women aged 15-19 (the relevant age compatible with any effect on the timing of fertility).

**Table 2:** ***Descriptive Statistics, rural young women, individual panel dataset***

| *Time-varying characteristics* | Mean (2004) | SD (2004) | Mean (2011) | SD (2011) |
|---|---|---|---|---|
| Had a child | 0.03 | 0.18 | 0.54 | 0.49 |
| Affected by 1-lag drought | 0.00 | 0.00 | 0.34 | 0.47 |
| Affected by 2-lag drought | 0.05 | 0.22 | 0.13 | 0.33 |
| Age (years) | 14.89 | 0.81 | 21.89 | 0.81 |
| Father ill or dead | 0.08 | 0.27 | 0.18 | 0.39 |
| Mother ill of dead | 0.00 | 0.20 | 0.12 | 0.33 |
| Enrolled in school | 0.88 | 0.32 | 0.16 | 0.38 |
| Highest grade completed (number) | 1.02 | 1.69 | 5.81 | 3.55 |
| Number of new brothers | 0.46 | 0.92 | 0.33 | 0.74 |
| Number of new sisters | 0.46 | 0.91 | 0.31 | 0.74 |
| Number of health centers in the village | 1.82 | 1.32 | 2.22 | 1.77 |
| Cohabitation | 0.02 | 0.14 | 0.54 | 0.50 |
| Number of children | 0.04 | 0.19 | 0.85 | 0.92 |
| Internal migrants | 0.03 | 0.18 | 0.29 | 0.46 |
| Working in any sector | 0.21 | 0.41 | 0.84 | 0.36 |
| (of which) Working in the agricultural sector | 0.93 | 0.24 | 0.86 | 0.34 |
| Hours spent in the agricultural sector (previous 7 days) | | | 27.28 | 15.52 |
| *Time-invariant characteristics* | Mean | | SD | |
| Father has no education | 0.51 | | 0.50 | |
| Father has completed primary | 0.16 | | 0.38 | |
| Father has completed college | 0.31 | | 0.46 | |
| Mother has no education | 0.58 | | 0.49 | |
| Mother has completed primary | 0.24 | | 0.43 | |
| Mother has completed college | 0.16 | | 0.37 | |
| Household assets in 2004 (0 to 100) | 19.70 | | 16.77 | |
| Household cultivates land in 2004 | 0.35 | | 0.48 | |
| Ethnicity: Merina | 0.22 | | 0.41 | |
| Ethnicity: Betsileo | 0.16 | | 0.37 | |
| Ethnicity: Betsimisaraka | 0.09 | | 0.29 | |
| Ethnicity: Other | 0.05 | | 0.50 | |
| Paved road in village* | 0.12 | | 0.33 | |
| Paddy fields irrigated by dams or pumping stations* | 0.49 | | 0.50 | |
| Living in an agric household | 0.79 | | 0.40 | |
| Climatic zone 1 (Equatorial rainforest, fully humid) | 0.14 | | 0.35 | |
| Climatic zone 2 (Equatorial monsoon) | 0.20 | | 0.40 | |
| Climatic zone 3 (Equatorial savannah with dry winter) | 0.14 | | 0.35 | |
| Climatic zone 4 (Steppe climate – hot steppe) | 0.03 | | 0.17 | |
| Climatic zone 5 (Warm temperate, fully humid – hot summer) | 0.07 | | 0.26 | |
| Climatic zone 6 (Warm temperate, fully humid – warm summer) | 0.19 | | 0.39 | |
| Climatic zone 7 (Warm temperate, dry winter – hot summer) | 0.11 | | 0.31 | |
| Climatic zone 8 (Warm temperate, dry winter – warm summer) | 0.08 | | 0.27 | |
| Number of observations | 572 | | | |

*Source*: Authors' elaboration from the Madagascar Young Adult Survey and EPSPAM. Drought data are based on the African Rainfall Climatology, version 2, National Oceanic and Atmospheric Administration. * These data come from the 2001 Commune Census.

**Table 3:** *Effects of drought on Completed fertility, rural women aged* $44 - 49$

| Regressors | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Total droughts at 15-19 | 0.448** | 0.448** | 0.485* | 0.485* |
| | (0.191) | (0.186) | (0.274) | (0.251) |
| Total droughts at 20-24 | 0.360 | 0.360 | 0.305 | 0.305 |
| | (0.238) | (0.236) | (0.279) | (0.254) |
| Total droughts at 25-29 | -0.100 | -0.100 | -0.119 | -0.119 |
| | (0.279) | (0.264) | (0.360) | (0.333) |
| Total droughts at 30-34 | 0.228 | 0.228 | 0.290 | 0.290 |
| | (0.239) | (0.226) | (0.310) | (0.279) |
| Total droughts at 35-40 | 0.154 | 0.154 | -0.001 | -0.001 |
| | (0.250) | (0.237) | (0.337) | (0.308) |
| Age FE | yes | yes | yes | yes |
| Grid Cell FE | yes | yes | yes | yes |
| Birth's Year FE | yes | yes | yes | yes |
| With migrants | yes | yes | no | no |
| Spatial Correlation | no | yes | no | yes |
| R2 | 0.186 | – | 0.175 | – |
| Observations | 1,611 | 1,611 | 1,069 | 1,069 |

*Source*: Authors' elaboration from the 1997 and 2008 Madagascar Demographic and Health Surveys in rural areas; droughts variables are constructed from the CRU series.

*Notes*: FE = fixed effects. Robust standard errors are clustered on the grid cell and are shown in parentheses. In columns (2) and (4) we account for spatial correlation across the grid cells within a radius of 50 km (the median distance across the grid cells) by following Conley (1999). Estimations are weighted by sampling weights. *** p<0.01, ** p<0.05, * p<0.1.

**Table 4:** ***Mechanisms – Effect of drought on cohabitation, schooling, time spent in farming, being a wage or self-employed worker, migrating and number of sex partners, women aged 15-19 years old, rural areas***

| | **Schooling** | **Migrating** | | **(ln) hours past 7 days** | | **Wage or self-employed worker last 12 months** | | **Cohabitation** | **Number of sex partners last 12 months** |
|---|---|---|---|---|---|---|---|---|---|
| | **Women** | **Women** | **Men** | **Women** | **Men** | **Women** | **Men** | **Women** | **Women** |
| Regressors | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Drought | -0.069* | -0.005 | 0.010 | _-0.467***_ | _0.377***_ | - | - | 0.016 | 0.314 |
| | (0.036) | (0.006) | (0.012) | (0.109) | (0.074) | - | - | (0.029) | (0.275) |
| Drought (1 year lag) | -0.042 | _-0.212**_ | _0.010_ | _0.368_ | _0.572***_ | -0.178*** | -0.076 | 0.081** | 0.253* |
| | (0.044) | (0.009) | (0.011) | (0.207) | (0.189) | (0.031) | (0.111) | (0.033) | (0.136) |
| Additional controls | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Age FE | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Grid/SBUs FE | yes | yes | yes | yes | yes | no | no | yes | no |
| Year FE | yes | yes | yes | no | no | yes | yes | yes | no |
| Avg outcome | 0.593 | 0.061 | 0.045 | 3.075 | 3.269 | 0.431 | 0.268 | 0.062 | |
| R2 | 0.374 | 0.843 | 0.848 | 0.331 | 0.348 | 0.152 | 0.079 | 0.071 | 0.020 |
| Observations | 2,313 | 2,585 | 2,507 | 297 | 294 | 3,778 | 1,173 | 2,213 | 617 |

*Source*: Authors' elaboration from the Madagascar Young Adult Survey and EPSPAM (columns (1)-(5) and (8)). Column (6) uses DHS 1997 and 2008. Column (7) uses DHS 2008. Column (9) uses DHS 1997.

*Notes*: LPM = Linear Probability Model; FE = fixed effects; SBUs = Satellite-based units. Coefficients in italics mean that the per-row difference is statistically different from zero (Wald test), i.e., (2) Vs. (3), (4) Vs. (5) and (6) Vs. (7). Robust standard errors clustered on climatic zones-year are shown in parentheses. Women in Columns (4) and (5) are aged 21, 22 or 23 as the outcome used in these columns was only observed at the time of the survey. Additional controls in (1) are the number of siblings, if the father (mother) is ill or dead, if the father (mother) is currently working, if the cohort member lives in the original household surveyed in 2004, the entry age at school, ethnicity, the father's education level, the mother's education level, household asset in 2004, the number of health centers in the village, the number of primary/secondary schools in the village, a dummy indicating if the household cultivated land in 2004, if the village has access to a paved road and to irrigation in 2001, and dummies for climatic zones. Additional controls in (2)-(5) and (8) are: if woman at school in time t-1, highest grade, assets in 2004, if father ill or dead, if mother is ill or dead, ethnicity, father's education level, mother's education level, if village has access to a paved road, number of health centers in the village, if village has access to an irrigation system and climatic zones. (5), (6) and (9) control for women's education level; *** p<0.01, ** p<0.05, * p<0.1.

**Table 5:** ***Marginal effects of drought on women childbearing during adolescence*** ($16-21$ ***years old), DHS data***

| Regressors | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Drought (1 year lag) | 0.005 | 0.005 | 0.005 | 0.011 | 0.029** | 0.005 |
| | (0.005) | (0.003) | (0.006) | (0.008) | (0.012) | (0.006) |
| Drought (2 years lag) | 0.010*** | 0.010*** | 0.011*** | 0.020*** | 0.002 | 0.008* |
| | (0.004) | (0.003) | (0.004) | (0.005) | (0.010) | (0.004) |
| Age FE | yes | yes | yes | yes | yes | yes |
| Grid Cell FE | yes | yes | no | yes | yes | yes |
| Birth's Year FE | yes | yes | yes | yes | yes | yes |
| DHS survey year | yes | yes | yes | yes | yes | yes |
| Individual FE | no | no | yes | no | no | no |
| Spatial Correlation | no | yes | no | no | no | no |
| Including Migrants | yes | yes | yes | yes | yes | no |
| Age at survey's date<26 | no | no | no | yes | no | no |
| Age at survey's date>43 | no | no | no | no | yes | no |
| R2 | 0.033 | – | 0.214 | 0.042 | 0.046 | 0.032 |
| Observations | 85,663 | 85,663 | 85,663 | 27,847 | 9,666 | 65,337 |

*Source*: Authors' elaboration from the DHS 1997 and 2008.
*Notes*: FE = fixed effects; SBUs = Satellite-based units. Robust standard errors are clustered on the grid cell and shown in parentheses under (1), (3)-(6); in column (2) we account for spatial correlation across the grids within a radius of 50 km (the median distance across the grids) by following Conley (1999). *** p<0.01, ** p<0.05, * p<0.1.

**Table 6:** ***Marginal Effects of drought on the timing of fertility in rural areas, women aged 16-21 years old, Madagascar Young Adult Survey (MYAS) and EPSPAM***

| Regressors | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Drought (1 year lag) | 0.028 | 0.062 | 0.052 | 0.063 |
| | (0.034) | (0.038) | (0.035) | (0.037) |
| Drought (2 years lag) | 0.069* | 0.120*** | 0.107*** | 0.096** |
| | (0.036) | (0.037) | (0.036) | (0.039) |
| Control variables | no | no | yes | yes |
| Age FE | yes | yes | yes | yes |
| SBUs FE | yes | yes | yes | no |
| Year FE | yes | yes | yes | yes |
| Individual FE | no | no | no | yes |
| Including Migrants | yes | no | no | no |
| R2 | 0.284 | 0.229 | 0.304 | 0.727 |
| Observations | 3,432 | 2,903 | 2,895 | 2,895 |

*Source*: Authors' elaboration on the Madagascar Young Adult Survey (2004) and EPSPAM (2011).

*Notes*: FE = fixed effects; SBUs = Satellite-based units. Robust standard errors are clustered on SBUs and shown in parentheses. Controls include: if a woman is at school, highest grade, assets in 2004, if father ill or dead, if mother ill or dead, ethnicity, father's education level, mother's education level, if village has access to a paved road, number of health centers in the village, if village has access to an irrigation system, climatic zones. *** p<0.01, ** p<0.05, * p<0.1.

**Table 7:** ***Effect Drought's effect on adolescent girls' childbearing: Role of dependence on rainfed agriculture, women aged 16-21 years old (MYAS and EPSPAM data)***

| | **Agric & Rural HH** | **Non Agric & Rural HH** | **Urban HH** | **All Rural HH** |
|---|---|---|---|---|
| Regressors | (1) | (2) | (3) | (4) |
| Drought (1 year lag) | 0.065* | -0.073 | -0.001 | 0.111** |
| | (0.036) | (0.045) | (0.019) | (0.045) |
| Drought (2 years lag) | 0.108*** | 0.109 | 0.012 | 0.144*** |
| | (0.038) | (0.083) | (0.029) | (0.046) |
| Drought (1 year lag) x | | | | -0.117* |
| Irrigation | | | | (0.065) |
| Drought (2 year lag) x | | | | -0.096 |
| Irrigation | | | | (0.063) |
| Additional controls | yes | yes | yes | yes |
| Age FE | yes | yes | yes | yes |
| SBUs FE | yes | yes | yes | yes |
| Year FE | yes | yes | yes | yes |
| R2 | 0.303 | 0.541 | 0.367 | 0.316 |
| Observations | 2,648 | 247 | 1,099 | 2,895 |

*Source*: Authors' elaboration from the Madagascar Young Adult Survey and EPSPAM.

*Notes*: LPM = Linear Probability Model; FE = fixed effects; SBUs = Satellite-based units. (1) uses women in agricultural households and rural areas only; (2) uses women in non-agricultural households and in rural areas only; (3) uses women in urban areas; (4) uses women in rural areas and adds the interaction between droughts and access to the irrigation system. Robust standard errors clustered on climatic zones-year are shown in parentheses. Additional controls are: if woman at school, highest grade, assets in 2004, if father ill or dead, if mother ill or dead, ethnicity, father's education level, mother's education level, if village has access to a paved road, number of health centers in the village, if village has access to an irrigation system, climatic zones. *** p<0.01, ** p<0.05, * p<0.1.