# *"Nari Shakti"* - Women's Relative Power and Productivity in Rural India: Two Essays

by

Monica Shandal

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in

Agricultural and Resource Economics

Department of Resource Economics and Environmental Sociology
University of Alberta

**Abstract**

This thesis is comprised of two essays on rural villages in India. The following will provide a brief abstract for each of the essays, where one focuses on the women's power – infrastructure relationship (1) and another on agricultural productivity relative to men (2).

(1)

Inequality between men and women is pervasive even though gender equality is regarded as a basic human right. Compared to men, the average woman attains lower education, participates less in the formal labour market, receives lower wages, owns fewer resources, and exhibits weaker bargaining positions in household decision-making processes. In India, women and girls frequently face social and structural barriers. Policymakers regularly employ gender-sensitive measure to attempt to close the inequality gap, but such policies are extremely difficult to implement correctly. Rather, the use of gender-neutral interventions such as infrastructure is becoming increasingly more common.

Using big data[1] comprised of both primary and secondary data from rural India and a novel econometric approach, this paper seeks to quantify the causal effect of infrastructure development – specifically roads – on women's power (e.g. women's decision making and bargaining power within the household). We use a fuzzy regression discontinuity design that exploits program rules from a national rural road program to estimate the effects of the road on an aggregate index of women's empowerment as well as several disaggregated measures to get at different dimensions of women's household decision making.

[1] Big data refers to large data that requires the use of additional mechanisms (e.g. machine learning or artificial intelligence) and software (e.g. Python and MATLAB) to effectively manage and use the data, instead of strict econometrics.

We find that women experience an overall drop in decision making power. This result is found to be largely driven by a drop in agricultural decision making (e.g. household production). However, we also observed an increase in decision making power in non-agriculture decision making (e.g. household consumption, labour and financial/ land markets). Overall the shifts may in decision making and power may be a signal of rural transformation.

(2)

Understanding women's productivity with respect to agricultural production, frequently requires the use of the collective household model. The collective household model maintains that male and female household members with different preferences maximize household utility and achieve Pareto efficient outcomes through cooperation and bargaining. However, a growing body of literature examining the validity of the Pareto efficiency assumption has found that plots of land managed by women are frequently less productive compared to those farmed by men. The discrepancy in productivity is attributed to differences in the inputs used on male and female-owned plots within the household. Thus, a reallocation of land from women to men (keeping all else constant) could significantly increase total agricultural production. Therefore, scholars have continually sought to explain if women farmers are inherently less productive then men farmers; or if the gender-differentiated profits can be explained by differences in the constraints faced by women– no real answer has been found.

This paper examines the issue of women's agricultural productivity (inefficiencies in yields between women and men-owned plots) using a large and detailed plot-level dataset collected from residents of rural India. We characterize the Pareto (in) efficiency between men and women owned plots in two ways; we study the variation in inefficiencies across observed

and unobserved heterogeneity. We find that women's ownership negatively impacts yields, but the magnitude of the effect is heavily influenced by observed plot, household and village characteristics. Moreover, when examining variation across the yields distribution (unobserved heterogeneity), we find that women and men owned plots display inequalities in yield. We further this study by also providing fresh insight into the intra-household model assumption of non-separability. Through the methods employed, we find that the assumption may not accurately represent rural households.

All in all, our findings support that development policies should go beyond general interventions that fail to recognize gender roles, rather policies may increase effectiveness by exclusively target women. Increasing the productivity of women engaged in agriculture is believed to yield high returns in the form of greater empowerment for women, increased welfare for their households, and increased productivity of the agricultural sector.

## Preface

This thesis is an original work by Monica Shandal. The research project, of which was part of this, received research ethics approval from the University of Alberta Research Ethics Board, Project Name “Causal Effect of Public Infrastructure on Women’s Empowerment in Rural Rice Farming Communities of India”, No. Pro00084882, October 22nd, 2018.

## Dedication

To my parents, Rajinder and Amita Shandal.

## Acknowledgements

To begin I would like to thank my supervisors in REES, Drs Sandeep Mohapatra and Brent Swallow for their guidance, and freedom during my thesis journey. Both of you allowed me to explore and develop my passions, I am beyond thankful for your support. Thank you Dr Sandeep Mohapatra for constantly believing in me (even when I didn't). You helped me grow so much academically, professionally, as well as personally. I know I might not have been the easiest student, so thank you for putting up with the countless meetings and emotions. You have become an amazing mentor and I will never be able to express my gratitude. Thank you Dr Brent Swallow for sparking my interest in international development. I wouldn't have been able to pursue such a project if it weren't for you.

Thank you my supervisor in India from the International Rice Research Institute Agri-Food Policy Platform, and specifically Dr Prakashan Chellattan Veettil for providing me the ability to follow my interests. Thank you for not only my data but also the opportunity to travel to India and have many amazing first hand experiences.

Thank you to my friends for providing many welcomed distractions from my thesis; with a special thanks going to Lakshita Tiwari, Roxana Zambrano, and the rest of the L1 squad.

Lastly and most importantly, thank you to my family (Dad, Mom, Manisha, Rajat, Clifford and Dot). You provided me with so much love and support– maybe now I'll get a job (but probably not).

Finally, I would also like to acknowledge the Social Sciences and Humanities Research Council of Canada (SSHRC) for primarily funding this research through the Joseph-Armand Bombardier CGS-M Scholarship.

**Table of Contents**

## List of Tables

## List of Figures

# Paper 1: The Causal Effect of Public Infrastructure on Women's Power in Rural Communities of India: A Fuzzy Regression Discontinuity Design

## 1. Introduction

Inequality between men and women is pervasive even though gender equality is regarded as a basic human right. Yet, nowhere in the world are women equal to men (OECD 2014; UNDP 2019; United Nations n.d.; UN Women 2018). Disadvantages experienced by women are grounded in household, societal, and structural barriers, some of which have long historical roots. These barriers in turn influence the livelihoods and well-being of women and their families (Schultz 2002). Compared to men, the average woman attains lower education, participates less in the formal labour market, receives lower wages, owns fewer resources, and exhibits weaker bargaining positions in household decision-making processes (World Bank 2011).

The issue of gender equality is especially germane in developing countries, where gender discrimination is regularly associated with deep-rooted expectations, social conventions and cultural norms, as seen in India. India is one of the largest countries in terms of population and economic growth, however, the country continues to have one of the largest levels of gender disparity in the world (Asian Development Bank 2018; World Bank 2017). As reported in the World Economic Forums Global Gender Gap report (2018), India is ranked 108$^{th}$ of 149 countries, far below the global average. A driving force behind this poor ranking is the fact that women are often marginalized in external circumstances (e.g. economic and educational opportunities) as well as within their own homes (Sharma 2016). Empowerment policies can help in this regard by closing the disparities between men and women. Scholars argue that women's empowerment policies can reduce gender inequality while also contributing to overall economic development (Montenegro et al. 2016).

Women's empowerment and economic development are dual outcomes: development plays a major role in driving down inequalities between men and women, and empowering women contributes to economic development (Duflo 2012). Underlying this instrumental value of women's empowerment is the general case that realized gains in women's opportunities lag behind gains in women's capabilities (World Bank 2006). Thus, women's empowerment is also smart economics: investing in women and girls will spur development because increases in womens' opportunities yield rewards for men, children and the broader society (World Bank 2006;). Likewise, women are also considered an under-utilized resource with the capacity to increase productivity, child education levels, and overall family health (Smith and Haddad 2015). A growing body of evidence supports the case for women-centered investments, including female-centric cash transfers, land titlements, and education and health programs (Ambler and De Brauw 2017; Duflo 2000; World Bank 2006). Therefore governments and non-profit organizations have continued to heavily invest resources and time in women's empowerment (Harper et al. 2014;  Gates 2014).

However, female-centred empowerment policies are difficult to implement. Problems of incorrect targeting, unintended consequences, and information asymmetry frequently plague programs designed to tackle gender inequality (Salia et al. 2018; Frey and Osborne 2017; Sveiby et al. 2009). Specifically, incorrect targeting has resulted in self- and biased selection within programs. A study conducted by Hashemi et al (1996) found that the effects of selection bias in some rural credit programs in Bangladesh did not empower women, rather the programs made domestic situations much worse. While, another study conducted by Husain et al (2014) found that self-selection into self-help groups in India often leads to ineffective programs. This is largely due to a lack of participation, in such programs, from individuals who are most in need of empowerment. Moreover, information asymmetry between the household and policymakers can create obstacles for policies to be effective in reducing household level discrimination. The disempowerment of women within households has also been said to be a root cause of inequalities experienced at other social levels (Ali and Hatta 2012; Ganle et al. 2015).

The most challenging, yet perhaps the most effective mechanism to alleviate disparities between men and women is to minimize household discrimination. Yet, strengthening women's power within households is extremely difficult for policymakers. Programs that attempt to bring about the disintegration of social norms and cultures in order to alter the allocation of decision making power are unlikely to be successful (Tomich et al. 1997). This can be illustrated for the India context. Skoufias (1993) found that girl children were more likely to be withdrawn from formal educational institutions in order to assist with household tasks and chores, while boys were more likely to remain in school to completion. Families commonly exhibit a higher affinity to invest in boys, because in traditional Indian culture, it is the sons' responsibility to take care of their parents in old age, while married daughters are expected to move away with their husband's families (Filmer 2005). To have an effective gender-sensitive policy mechanism in such a context, policymakers must first identify households that discriminate against their daughters, then target policies to such households, and lastly ensure that program benefits reach the disempowered women in those households (Alderman et al. 1995). An examination of current literature shows that there is no singular means to increase women's ability to participate in household decision making processes, rather, this is still an open question subject to much debate (Doss and Morris 2000; Gibbs et al. 2012; Unterhalter et al. 2014).

In contrast to specific gender-sensitive interventions that are reliant on a great deal of information and understanding, gender-neutral interventions, such as building bridges and roads are a promising alternative. Gender-neutral policies do not require the identification of discriminatory households or explicitly attempt to change behaviours in those households. Instead, infrastructure policies are implemented to promote universal coverage and access to basic facilities and services (Ghosh 2017; Moser 2012). Therefore, general infrastructure developments, like roads, have the potential to automatically address the plight of women and girls by facilitating gender-differentiated economic opportunities, as shown by economic theory (e.g. Alderman 1991). Rahman and Rao (2004) found that village infrastructure can lead to greater female involvement in household decision-making, thus bridging the gap of gender inequality within the village households. More generally, the strong positive correlation between rural development and income growth, has also been accredited with reducing overall levels of poverty (Mahmud and Sawada 2018; UNDP 1994) (see Besley and Burgess 2003; Dollar and Kraay. 2002; Ravallion 2001). Moreover, through increasing access to resources and services, individual wellbeing has also been positively impacted by road infrastructure (Aggarwal 2018). Similarly, infrastructure development has been linked to a variety of empowerment indicators including employment, education and health (Mahmud and Sawada 2018; Agénor 2006). A number of studies have conducted detailed analysis of direct and indirect effects of such gender neutral investments (Mellor 2017; Ghosh 2017).

Surprisingly there are no quantitative studies of the effects of infrastructure on empowerment. This study is the first to provide quantitative evidence on the causal effect of infrastructure development on women's empowerment and, thereby, on household decision making. This study also compliments current qualitative studies looking at the gender-differentiated effects of infrastructure. The overall goal of this study is to help strengthen the understanding of the impacts (both positive and negative) of large scale infrastructure programs. The identification of causal effects on empowerment, however, is a challenge using observational survey data on women's decision making outcomes and the presence of roads, because of selectivity issues and the multitude of variables that affect empowerment. Thus, most studies of empirical work on empowerment report associations or correlations rather than causation.

To identify the causal effects, we combine a large detailed survey collected by the International Rice Research Institute (IRRI) in 2016 and a big-dataset on infrastructure in India that we compiled for this study, along with the recent advances in econometrics of impact evaluation. We use a regression discontinuity method (RD) which results in an identification strategy similar to that of a randomized control trial (RCT). Similar to a RCT, a regression discontinuity relies on the use of statistical equivalence and counterfactual groups around a program uptake threshold. We develop a model based on the novel *fuzzy regression discontinuity design* to derive the causal identification of the effects of roads on power. We use the primary data collected by IRRI to examine the bargaining position of men and women in households using predefined indices. Our approach exploits differences in the probability of treatment (of getting a road) across villages under India's Pradhan Mantri Gram Sadak Yojana (PMGSY) program to estimate infrastructure impacts on women's power.

Insights from the empirical work will be relevant to empowerment and agricultural programs in the study area of eastern India. This study also adds to the growing research focusing on the PMGSY road program to examine the effects of roads on labour markets and migration, structural transformations, and agricultural production (Asher and Novosad 2017; Bell 2010; Aggarwal 2018; Shamdasani 2018).

## 1.1 Research questions, hypothesis and objectives

This study seeks to provide quantitative evidence on the causal impact of public infrastructure development on women's empowerment (measured by their decision making ability relative to men in their household) using data from rural India. We aim to understand how women's bargaining position within the household – their say in household decisions making processes (henceforth referred to as *power)* - have shifted due to the presence of a road. Specifically, we hope to answer the following question. *Do roads have any impact, positive or negative, on women's empowerment?* We believe that the effects of roads will be far reaching, far beyond the direct access and connection, and influence many areas of household decision making both on and off the farm. We hypothesize that the presence of a road can increase a women's power in the household through various channels: by creating upward shifts in demand for production activities that women have a relative comparative advantage in; or by lowering barriers that previously had prevented women from being able to meet market demands for their labor. These shifts can increase women's relative income and, thereby, contribute to their power. However, the direction of the absolute effects cannot be assigned prior. For instance, roads could pave the way for accessing jobs that males have a comparative advantage in, thereby, increasing men's relative income and their power within the household. Infrastructure effects on women's relative power in rural India, therefore, remains an open empirical question.

Due to our focus on rural households, we are particularly interested in women's involvement in agriculture and how household decisions shift in the presence of roads. However, to gain a comprehensive understanding of how women's household and social roles are unravelling due to better infrastructure, we also examine areas outside of household agriculture, such as decisions pertaining to household consumption and individual labour decisions. Typical processes of rural development in India, based on our fieldwork (Shandal 2019) and the literature of India's development patterns, are observed to move people out of agriculture into off-farm rural and urban labor markets, and non-farm entrepreneurial activities within and out of the farm. Thus another key question we focus on is: *Are the causal impacts of infrastructure on women's empowerment consistent with these broader processes of rural transformation, giving women greater decision-making power over their off-farm and extra-household entrepreneurial decisions while reducing their power over housework ? Or are roads making women more home and farm centric—squeezing their decision-making roles even more into farm production and child expenditure patterns?*

To answer these questions, the *outcome variables* we consider consist of an aggregate index of women's empowerment as well as several disaggregated measures within four broad dimensions of women's household decision making. First, we create an aggregate index called *women's overall power* using a modified version of the Abbreviated Women's Empowerment in Agricultural Index (A-WEAI) created by the International Food Policy Research Institute (IFPRI) (Alkire et al. 2012). Next, we break down the *women's overall power* into the following broad categories of economic variables that depict smallholder households in developing countries (Singh, Squire and Strauss 1986): household production (decisions on *production mix and output*, *marketable surplus*, and *own-farm labor supply*); household consumption (*household expenditures* including children's education and *family planning*); labour market (which pertain to *off-farm labor supply* decisions about individuals wage and salary employment); and financial and land market (which include decisions over *access to credit* and *land ownership*). As a whole, we examine nine outcomes to characterize the response of women's empowerment to infrastructure development: *women's overall power, production mix and output*, *marketable* *surplus*, and *own-farm labor supply*, *household expenditures, family planning*, *off-farm labor supply, access to credit,* and *land ownership* (see Appendix A for an outline on how indices were made).

### 1.2 Paper structure

The remainder of this paper is organized in the following order. Section two provides the conceptual model of decision making. Section three outlines the context of the study and the data used. Section four explains the methods, both in an empirical and practical manner. Section five displays the results and the findings of the study. Lastly, the discussion and conclusion are respectively in section six and seven.

## 2. Household decision making: a conceptual framework

We present a simple conceptual framework to highlight the effects that public infrastructure, specifically rural transportation infrastructure, have on women's power. We look at the power of women in villages with and without a road treatment. We model household decision making using a collective model where the power of household members plays an important role in the determination of household decisions; in this model we will look at the allocation of decision-making between the head male and the head female (Alderman et al. 1995; Duflo 2000; Zepeda and Castillo 2006).

The household is comprised of two decision makers, one man (m) and one woman (f). The household utility function is expressed as a weighted sum of the member's individual utility function given by equation 1 (Bertocchi et al. 2014; Browning et al. 2007).

$$U_h = \lambda U_f(\cdot) + (1-\lambda) U_m(\cdot) \qquad (1)$$

Where a household's (h) household utility is a weighted sum of individual utilities ($U_h$), which is the sum of the individual utility function for the decision-making male ($U_m$) and for the decision-making female ($U_f$). An individual's utility is a function of their individual preferences for consumption of private goods, public goods and leisure ($\cdot$). $\lambda$ is the utility weight of the female decision maker, and ranges from 0 to 1, and $(1-\lambda)$ is the utility weight of the male decision maker. Within the household, $\lambda$ may also be interpreted as the relative decision making power of the female decision maker. The individual with the higher weighted power displays a higher degree of input in the household decision making process. For instance, if $\lambda$ is 1, the female would be exclusively in charge of the decision, as the male power would be equal to 0.

With respect to the effects of a road on the decision making ability, we believe there are three mechanisms by which household consumption (and production patterns which are abstracted in our simple framework) can be influenced by the advent of a road. Roads have the potential to: (1) create shifts in the preferences that make up individual utility (e.g. shifts in consumption patterns, production technologies and labour participation); (2) shifts in power which derive from the changes in relative earnings of women in the household (e.g. shifts in λ); and (3) shifts in the household's budget constraint (e.g. shifts in income, and shifts in prices). These three mechanisms may lead to changes in household decision making, thus public infrastructure investments may be observed as an important tool for rural development, with one component ( influence 2 listed above) serving also as a tool for women's empowerment. Such effects (e.g. shifts in the consumption patterns and prices) are frequently taken for granted and over-looked in large scale investments.

Empirically, each hypothesis leads to predictions and testable implications in structural sense. However, we take a reduced form approach and examine the second channel – how does infrastructure effect women's bargaining power. Implications for household's consumption outcomes will depend on all three channels. It is likely, that villages with a road will provide women with the direct (access and connection) and indirect (income) resources needed to gain power. Women with more power will have greater autonomy in the household decision process, which in turn will allow them to influence household decision making processes to a greater extent.

## 3. Context & Data

The data for this study and the estimation of the economic impacts of new rural roads required the construction of a village level dataset for eastern Indian states; which combined secondary data from the Government of India on the PMGSY program with the socioeconomic survey conducted by IRRI. Additionally, focus groups were conducted in order to gain insights into the field level realities of the PMGSY program and its effects. In this section, we describe each data component individually.

### 3.1 International Rice Research Institute Rice Monitoring Survey Data

The survey conducted was focused on the eastern region of India, specifically the states of Bihar, Odisha, West Bengal, and Eastern Uttar Pradesh (Figure 1-1). This region is classified as one of the least developed in India, and consistently lags behind the rest of the country in many development indicators, as displayed in Table 1-1 (Reserve Bank of Inida 2013; World Bank 2018). While many states have made progress in areas like education and health, India as a whole continues to exhibit a number of social and structural barriers that have resulted in many adverse effects, including large gender gaps in several aspects of social and economic life (World Economic Forum 2018).

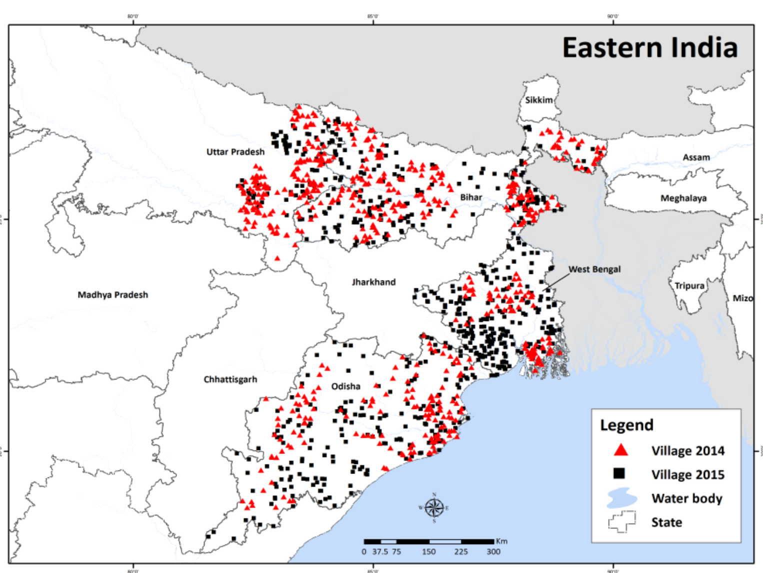
The individual and household level socioeconomic data used in this study were collected by IRRI as part of their annual Rice Monitoring Survey (RMS). The RMS project (implemented through the support of the Bill and Melinda Gates Foundation) is an annual survey of agriculture dependent (rural) households that collects information on socioeconomic status, farm practices, and grown seeds, among other indicators (Yamano 2015). For this study, we focused on the 2016 RMS survey which collected data on changes in household production practices (e.g. varietal turnover and climate change adaptation), as well as gender-disaggregated data on household activities and decision making (Yamano et al. 2017). In order to meet the objectives outlined for this study, we primarily focused on the gender-disaggregated data.

The selection process of the villages used in this study was dependent on the villages included in the 2016 RMS survey. Villages were randomly selected according to the following steps: (1) rural villages were randomly selected from the 2011 Census of India, where the total number of sample villages selected in each state was proportional to the total number of rural villages in the state; (2) all households in the selected villages completed an initial census by IRRI on household and production characteristics; and (3) from the households included in the initial census that had male and female decision makers, approximately twelve were selected randomly from each village to be questioned in the 2016 RMS survey. Gender-sensitive enumeration methods were employed to minimize the gender influence and gather the most truthful responses. Male enumerators surveyed male respondents and female enumerators surveyed female respondents. (Yamano et al. 2017).

Village selections across the states can be seen in Table 1-2. The greatest number of observations were collected for Odisha, followed by Bihar, West Bengal and Eastern Uttar Pradesh. The total dataset included 720 villages, 8,639 households, and 38,756 individuals across the four states (Table 1-2).

The IRRI survey provided detailed information on women's empowerment and decision making abilities within the household. Using this information we created the nine outcome variables refereed to earlier as a way of testing the effects of infrastructure on women's power. Appendix A outlines the methods used to produce the outcomes. We discuss the big-data on roads in the upcoming subsection.

**Figure 1-1**: Map of Eastern India depicted IRRI Rice Monitoring Villages in 2014 and 2015




Note: This map is a depiction of all IRRIs Rice Monitoring Survey villages. The area is comprised of four states in the eastern region of India: Bihar, Odisha, Eastern Uttar Pradesh and West Bengal. The 2014 villages provide an approximation of the villages used in the 2016 as same villages were targeted.

**Table 1-1**: State wise development indicators for all states in India summarized from the World Banks "India State Briefs" for 2013

| | **Total Population (millions)** | **Poverty Rate (%)** | **Literate (% adults)** | **Electrification (%households)** | **Drinking Water on Premises (%households)** | **Open Defecation (%households)** | **Road Density (km / million people)** |
|---|---|---|---|---|---|---|---|
| **Assam** | 31 | 32 | 82 | 61 | 81 | 12 | 8,990 |
| **Bihar** | **104** | **34** | **58** | **31** | **73** | **68** | **1,306** |
| **Chhattisgarh** | 26 | 40 | 71 | 87 | 27 | 68 | 2,915 |
| **Gujarat** | 60 | 17 | 73 | 95 | 70 | 35 | 2,266 |
| **Haryana** | 25 | 11 | 75 | 96 | 77 | 17 | 1,657 |
| **Himachal Pradesh** | 7 | 8 | 79 | 97 | 61 | 22 | 7,275 |
| **Jharkhand** | 33 | 37 | 62 | 69 | 29 | 74 | 783 |
| **Karnataka** | 61 | 21 | 73 | 97 | 55 | 45 | 4,902 |
| **Kerala** | 33 | 8 | 94 | 96 | 76 | 2 | 6,423 |
| **Madhya Pradesh** | 73 | 32 | 67 | 87 | 34 | 61 | 2,729 |
| **Maharashtra** | 112 | 17 | 80 | 94 | 64 | 34 | 3,487 |
| **Odisha** | **42** | **33** | **68** | **70** | **27** | **73** | **6,002** |
| **Punjab** | 38 | 8 | 75 | 98 | 87 | 16 | 3,347 |
| **Rajasthan** | 69 | 15 | 59 | 82 | 51 | 58 | 3,569 |
| **Tamil Nadu** | 72 | 12 | 78 | 98 | 47 | 42 | 3,152 |
| **Uttar Pradesh** | **200** | **29** | **60** | **51** | **63** | **61** | **1,987** |
| **Uttarakhand** | 10 | 11 | 77 | 95 | 61 | 16 | 5,143 |
| **West Bengal** | **91** | **20** | **72** | **78** | **36** | **30** | **3,418** |
| **India** | **1211** | **22** | **70** | **80** | **56** | **44** | **3,231** |

Note: This table presents the indicators calculated my the World Bank in their "India State Briefs" (World Bank 2018)

**Table 1-2**: Village, household and individual level composition by state, Eastern India, 2016

| | Village composition (%) | Household composition (%) | Individual Composition (%) |
|---|---|---|---|
| **Bihar** | 176 (24.4%) | 2,112 (24.4%) | 10,325 (26.6%) |
| **Odisha** | 225 (31.3%) | 2,699 (31.3%) | 11,203 (28.9%) |
| **Uttar Predash (Eastern)** | 151 (21.0%) | 1,812 (21.0%) | 9,639 (24.9%) |
| **West Bengal** | 168 (23.3%) | 2,016 (23.3%) | 7,589 (19.6%) |
| **Total** | 720 (100%) | 8,639 (100%) | 38,756 (100%) |

Note: This table presents the breakdown of observations by state. The first column represents the number of villages, the second the number of households and the third the number of individuals.

### 3.2 Pradhan Mantri Gram Sadak Yojana Government Data

For this study we focused on the road infrastructure produced through the Pradhan Mantri Gram Sadak Yojana – "Prime Minister Village Road Program." The PMGSY program was launched in 2000 by the Indian federal government as part of its poverty reduction strategy with the intention of providing connection to external market for unconnected villages across India (OMMAS n.d.; Asher and Novosad 2017). The program was funded by the World Bank, Asian Development Bank and federal Ministry of Rural Development. While the program was primarily overseen by the federal Ministry of Rural Development, program implementation was delegated to state governments. The goal of the program was to combat the issue of access and connection by providing new or updated all-weather paved roads to the greatest number of rural villages at the lowest possible price. National eligibility criteria guidelines were used to prioritize roads to be constructed. Priority was given to the construction of direct link routes (roads terminating in the village) to connect fully unconnected villages, over indirect link routes (roads passing through a village to another large road) to partially connected villages (Government of India 2012; Asher and Novosad 2017).

Under the program, villages were sanctioned (given approval) to receive a road based on the village population in 2001 as recorded in the National Population Census of India (Government of India n.d.). Initially, larger villages were targeted and smaller villages added in later years. Villages were targeted based on three principal population thresholds of 1000, 500, and 250 village residents. The implementation rules were applied on a state-by-state basis, thus state level governments and program officials played a significant role in the determination and allocation of PMGSY roads. In some cases, political opinions and economic importance influenced the priority given to some villages. Likewise, lower population thresholds were used for desert and tribal villages, as well as in hilly states and districts affected by left-wing extremism (Asher and Novosad 2017). Prior to the commencement of the PMGSY program, program officers developed District Rural Road Plans that delineated the "core network" of existing roads and the new roads that would be required to connect every eligible village. By 2018, over 585,000 kilometers of roads had been constructed, with over 120,000 new connectivity works (OMMAS n.d.).

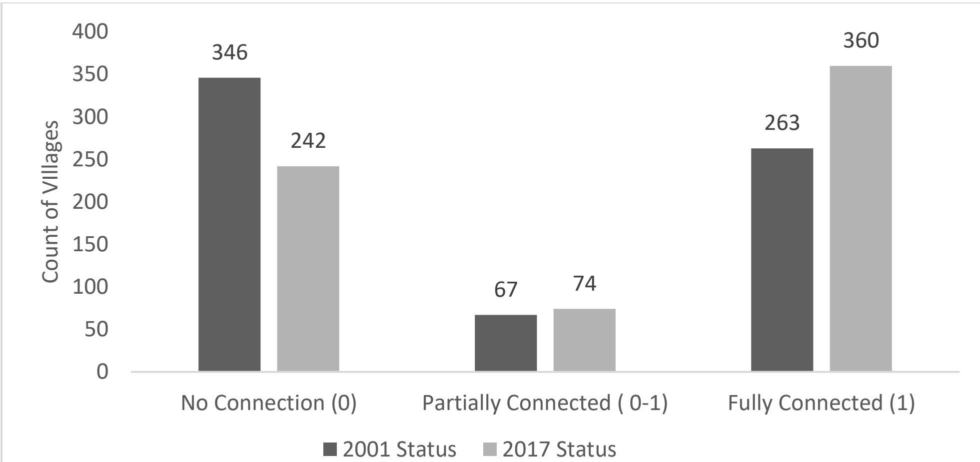
The data pertaining to the PMGSY program were collected from an online repository run by the Monitoring and Accounting Systems in India (n.d.). These data are publicly available and include information on the year a village was approved for a road (sanctioned), costs of paved road construction, connection status, village population, and village characteristics (e.g. the presence of primary schools, medical centres, bus services and more). Data were obtained at the village and habitation level (a cluster level breakdown of the village).

All data was accessed in January 2017 using Python programming software, with Selenium, a web- based automation tool which provides modules for web scraping. Data postprocessing was completed using Python and MATLAB. Funding for the collection of the PMGSY data was contributed by The Support for the Advancement of Scholarship (SAS) administered through the University of Alberta's Office of the Provost.

A key village characteristic required for the analysis is connection status. Villages were considered connected if and only if ALL habitations in the village had an all-weather paved road connecting them to the core network of external markets by 2017. Villages were considered to be fully unconnected if NO habitations in the village had an all-weather paved road connecting them to external markets. Villages were treated by the program if some/all habitations in the village had received a road under the program between 2001 and 2017. Village connection status in 2001 (the beginning of the program) and 2017 (the end of the program for this study) can be seen in Figure 1-2. By 2017, the number of entirely unconnected villages dropped from 346 to 242, while the number of fully connected villages increased from 263 to 360.

The PMGSY government data were then matched with data from IRRI's 2016 RMS socioeconomic survey. Of the 720 villages included in the 2016 RMS study, approximately 94% were successfully matched with the PMGSY data. For this analysis, we restricted our sample to villages that were not originally classified as fully connected. Fully connected villages were eliminated from the analysis because they do not exhibit a change in connection, therefore identifying the effects of connection via a new road was not possible. Thus, all villages that were fully connected in 2001 were omitted. Therefore, a total of 263 villages were removed from the initial sample resulting in a usable sample of 413 villages across the four states.

**Figure 1-2**: Connection status in 2001 and 2017 for Eastern Indian villages included in our study




Note: This figure presents the connection status of villages in the year 2001 and 2017. Connection was defined as no connection (meaning no habitations were connected via all weather road) fully connected (meaning all habitations were connected via all weather road), and partial connection (meaning some habitations were connected via all weather road).

### 3.3 Focus Group Data

For the specific purpose of this study, we designed, developed and implemented focus group interviews in the state of Odisha. Focus groups were convened to understand the realized impacts of rural roads with respect to five key areas: employment, agriculture, government services, mobility, and day-to-day routines of women. Nine RMS villages were randomly selected from the available villages within a 300 km radius of the capital city of Odisha – Bhubaneswar. Selected villages were in Khordha, Angul, Jaipur, Nayagarh, and Puri districts of Odisha. The duration a village had a road varied among the selected villages, this allowed us to accurately gather information on the changes observed in the village caused by a road. Similar to the methods used in the 2016 RMS survey, gender sensitive methods were employed to allow participants to more freely express their views, meaning that female enumerators led discussions with female participants. In each village two gender differentiated focus groups were conducted with approximately 15 village respondents in each.

Focus groups were conducted in November 2018. The focus groups were conducted by a team of 4 enumerators who were contracted by IRRI, guided by the senior author of this paper. The focus groups were conducted in Odia and audio recorded. Enumerators then provided an English transcription of the proceedings. The information gained from the focus groups was used to inform the quantitative research methods and interpretation of results.[2]

## 4. Methods

This section serves to provide an outline of the empirical strategy, application, and estimation of RD design used for this study.

### 4.1 Empirical Strategy

Identification of the impact of infrastructure poses several empirical challenges, including the unavailability of data; self-selection of households into programs (e.g. households moving to areas with a road because of the greater opportunities); and endogeneity of the determinants of the program (e.g. roads are typically placed in more remote and isolated areas). Infrastructure developments are generally not randomly timed or placed due to the large financial investments and potential benefits to residents. This creates bias in the estimates of benefits experienced by households when infrastructure variables are used directly in the outcome regression equations. Thus the use of direct measures of infrastructure in OLS models (e.g. the presence of a road in a community) is not valid for identifying the causal impact of roads on household outcomes (Imbens and Lemieux 2007; Ozier 2011; Griliches 2006; Card 2001).

[2] Ethics clearance for conducting the focus groups was obtained from the University of Alberta Research Ethics Board 1 (Pro 00084882)

We overcome problems related to causal identification by using the PMGSY program to estimate the impacts of infrastructure on women's empowerment. As explained above, the road program is implemented under strict eligibility rules that are beyond the control of households and villages – making the program implementation truly exogenous. The running variable for the road program is the 2001 population, meaning that decisions pertaining to the program were made according to population levels at that time. In order to identify the causal impact, we compare villages that are encompassed in a bandwidth of villages directly above and directly below the relevant population threshold. At this point they are statistically equivalent counterfactual groups and all characteristics - with the exception of the probability of receiving a road - are considered equal. Villages above the predetermined critical threshold are believed to have a higher probability of receiving a road than villages below the threshold, because enforcement officials sanctioned villages to receive a PMGSY road based on whether or not the village population reaches the threshold. Thus at the threshold population level we expect to find a discontinuity in the probability of being sanctioned for a road, where villages above will be substantially higher than those below.

Villages were classified as eligible for a road if the population of the village was above the threshold (1000, 500, and 250) in the 2001 National Population Census. In this study we explicitly focused on the population threshold of 500 residents. The sample used in this study is relatively small (compared to the national program), thus of the three thresholds, the greatest number of villages were encompassed in a range surrounding 500.

Due to some degree of noncompliance of the strict eligibility rules by program officials in the PMGSY road prioritization and implementation, a fuzzy regression discontinuity design was used (Asher and Novosad 2017; ModU 2015). A frequently observed form of noncompliance, were the lower thresholds used for special status villages (e.g. tribal and remote) (Government of India 2012). Slight deviations from the strict rules were also attributed to the political and economic forces at play in India (Lehne et al. 2018). The deviations observed during the implementation of the PMGSY program do not impact all of the villages eligible for a PMGSY road under the program, therefore identification is still achievable using a fuzzy RD design.

Sharp RD are commonly used in "textbook" examples, while fuzzy RD are frequently used in practical real world applications because of the requirements needed for the data and implementation. Under a sharp RD, the probability of receiving a road (the treatment) would shift from zero to one once the village population reaches the threshold because every village is guaranteed to receive the treatment once the threshold is passed. A fuzzy RD differs in that the jump at the threshold is not a shift of probability from zero to one, but a significant shift of less than one, since all villages are not strictly following the program rules (Imbens and Lemieux 2007). Aligning with the assumptions and methods described by Imbens and Lemieux (2007), and Asher and Novosad (2017), the fuzzy RD estimator estimates the local average treatment effects (LATE) of receiving a new road in villages with population levels equal to or above the threshold as specified in equation 2.

$$\tau = \frac{lim_{pop \to T+E}\,[Y_v | pop_v = T] - lim_{pop \to T-E}\,[Y_v | pop_v = T]}{lim_{pop \to T+E}\,[Y_v | newroad_v = T] - lim_{pop \to T-E}\,[Y_v | newroad_v = T]} \qquad (2)$$

Where *v* is a village, $Y_v$ is the outcome of interest in a village, $pop_v$ is the village population listed in the 2001 National population census (the running variable), *T* is the population threshold of 500, and $newroad_v$ is an indicator variable for whether village $v$ received a new road under the program between 2001 and 2017.[3] The treatment effect $\tau$ depicted in equation 2 can be interpreted as the discontinuous change in the outcome variable at the population threshold (the numerator) divided by the discontinuous change in the probability of treatment (the denominator). The estimation derived in equation 2 pertains only to those households that were in villages that complied with the assignment rules of the PMGSY program.

For our bandwidth and estimation calculations, we followed Asher and Novosad (2017), Imbens and Lemieux (2007), and Lemieux (2011). To establish an optimal bandwidth we ran our models using a range of potential bandwidths to visually inspect an accurate and consistent estimation (Jacob et al. 2012). We ran models around the threshold at bandwidths of 500, 400, 300, 200 and 100. We find the optimal bandwidth to be 200, results from the bandwidth calculations can be seen in Appendix B.[4] Therefore, for our final estimations we restricted our sample to a bandwidth of 200 around the population threshold of 500 [*500 –200; 500 + 200*], which resulted in the running variable ranging from village population of 300 to 700 residents.

## 4.2 Econometric Model

### 4.2.1 Does the treatment probability shift at a population threshold?

We begin by estimating the following fuzzy RD design specification:

$$newroad_v = \beta_0 + \beta_1\{pop_v > T\} + \beta_2\,(pop_v - T) + \varepsilon \qquad (3)$$

[3] Specific variables used in this study and their definitions can be found in Table 1-3.

[4] We were unable to conduct precise bandwidth calculations due to our limited sample size, when focusing in on only villages that fell within smaller bandwidths the number of applicable villages was too restricted, leading to incomputable or insignificant results.

Where $\beta_0$ is a constant term, $pop_v > T$ is an binary variable signifying if village $v$ is above the 2001 population threshold, and $pop_v - T$ is village $v$'s deviation from the threshold, and $\varepsilon$ is the idiosyncratic error. Additional extended model were also used that included other polynomial terms added to the baseline equation.[5]

From the above equation, we determine if a discontinuity in the probability of receiving a road is present at the village population threshold. If a significant shift in the probability at the program threshold is present, the shift can be largely attributed to the program, as at this point there are no other differences in the villages (the only difference between the villages being that villages to the right of the threshold display a higher probability of receiving a road under the program, while villages to the left do not). The observed/ estimated discontinuity can be defined as the treatment effect, which represents the effect of the program on the village's probability of receiving an all- weather paved PMGSY road.

**4.2.2 Does women's power change at the threshold?**

Similarly to examining the probability of receiving a road, we are able to compare specified outcomes, in this study variables pertaining to women's power, in villages below and above the PMGSY threshold to show the effect of the program treatment on the outcome. Given the implementation structure of the program and result of equation 3 (a significant effect on the probability of receiving a road at the threshold) we are able to use village population as an approximation for receiving a road when examining power related outcomes. The effect on the outcome is estimated directly using the following fuzzy RD specification that instruments the

[5] Village controls and fixed effects were not included in the primary models as they are not necessary for the identification. Since they do improve the efficient of the estimator they will be used in robustness analysis reported in table 13 and 14.

treatment (new road/ connection) with village population above 500. For this study, the reduced form women's power equation (that will be specified with our nine different outcome variables as dependent variables in four separate models) is given by:

$$Y_{v,n} = \gamma_0 + \gamma_1 newroad_v + \gamma_2(pop_v - T) + \varepsilon \quad (4)$$

Where $Y_{v,n}$ is the outcome *n* in village *v*. Collectively, equation 3 and 4 allow us to examine and estimate the effects of the PMGSY program on women's power within the household. Specifically, the effect of the program can be interpreted as $\gamma_1$ in the above equation. $\gamma_1$ can be causally attributed to the presence of a road since at the threshold, as mentioned earlier, the villages are statistically identical. Thus, any changes in women's power outcomes to the left and the right of the threshold must be due to the treatment of roads.

**4.2.3 Alternative specifications**

In this study, we explore the effects of rural road development on the women's power through the use of four models. The models show the different magnitudes and persistence of the effect. Our estimation procedure is comprised of the following four models.

1. Baseline model:

$$Y_{v,n} = \gamma_0 + \gamma_1 newroad_v + \gamma_2(pop_v - T) + \varepsilon \quad (5)$$

2. Model with additional polynomial difference terms:

$$Y_{v,n} = \gamma_0 + \gamma_1 newroad_v + \gamma_2(pop_v - T) + \gamma_3(pop_v - T)^2 + \gamma_4(pop_v - T)^3 + \varepsilon \quad (6)$$

3. Model with additional polynomial interaction terms:

$$Y_{v,n} = \gamma_0 + \gamma_1 newroad_v + \gamma_2(pop_v - T) + \gamma_5\{pop_v > T\} * (pop_v - T) + \gamma_6\{pop_v > T\} * (pop_v - T)^2 + \gamma_7\{pop_v > T\} * (pop_v - T)^3 + \varepsilon \quad (7)$$

4. Complete model containing both polynomial difference and interaction terms:

$$Y_{v,n} = \gamma_0 + \gamma_1 newroad_v + \gamma_2(pop_v - T) + \gamma_3(pop_v - T)^2 + \gamma_4(pop_v - T)^3 + \gamma_5\{pop_v > T\} * (pop_v - T) + \gamma_6\{pop_v > T\} * (pop_v - T)^2 + \gamma_7\{pop_v > T\} * (pop_v - T)^3 + \varepsilon \quad (8)$$

Additional terms were added to increase the precision of the estimate generated. Power terms were added into the equation to capture nonlinearities that may be present in the infrastructure- power relationship. *Difference terms* $((pop_v - T), (pop_v - T)^2, (pop_v - T)^3)$ provide insight into the relationship for population above and below the threshold. While, *interaction terms* $(\{pop_v > T\} * (pop_v - T),\ \{pop_v > T\} * (pop_v - T)^2, \{pop_v > T\} * (pop_v - T)^3$ were added to account for the joint relationship between villages above the threshold and the distance a village is from the population threshold. Overall, the inclusion of *difference* and *interaction terms* improves the specification of the model to increase the accuracy of the estimate of the effect associated with the road (Cook and Shadish 2012). Regardless of the additional terms added, the causal effect of roads on the outcome is observed at the population threshold.

Our model was informed by insights gained through focus groups conducted by our team. Focus groups provided us with the key focus areas. For example, through the focus groups we determined that agriculture and employment were the most heavily impacted areas by the introduction of a road in a village. Communicating with villagers directly gave us a window into the livelihoods of residents.  All in all, the focus groups provided direction for component indices, and improved our understanding of the area and its people.

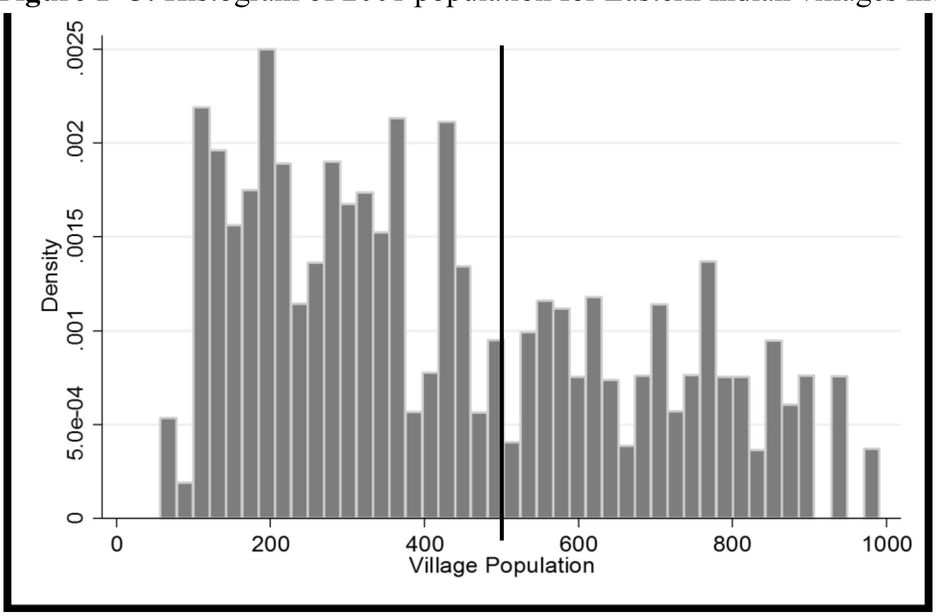
### 4.3 Setting the stage for the (above) econometric model: Regression Discontinuity Design Considerations

In order to justify the use of the fuzzy RD approach, we must prove (1) that there are no discontinuities in our predefined running variable, and (2) that the program rules are in fact followed.  Evidence of the first requirement is a smooth histogram of village population, evidence of the second requirement is a graphical jump in the probability of receiving a road (y-axis) and the village population (x- axis) at the population threshold of the program (Asher and Novosad 2017; ModU 2015). Additionally, the validity of the running variable is also an important determinant in justifying the use of fuzzy RD for the analysis.

For the entire PMGSY program, Asher and Novosad (2017) show that the population of villages is continuous and that there are no signs of manipulation in the running variable. This was proven both mathematically and visually, by having a smooth histogram and a significant result to the McCrary Test which determines the internal validity of the RD by examining discontinuities observed in the running variable (Asher and Novosad 2017; McCrary 2008). When looking specifically at the villages in our sample we observe a slightly uneven histogram (Figure 1-3). This may be attributed to a number of factors. One reason may be the fact that our sample is not representative of the entire population of India, rather our sample focuses solely on rural farming villages. Thus, the villages included in our sample have specific characteristics that are not typical of other villages (e.g. urban areas or non-farm dependent villages).

The concept of heterogeneous effects provides a deeper understanding to the uneven histogram observed in figure 1-3. Heterogeneous effects pertain to independent sub-populations, instead of the entire population. Different types of sub-populations are expected to experience different impacts from the treatment. In the context of our study, wealthy villages that receive a road may display different results than poor villages, while the effects of a road may also differ between urban and rural villages. Using the framework outlined by Athey and Imbens (2015), it can be seen that our sample is non-representative of all types of villages that received a road under the program. Rather, the sample of villages used in this study is a random selection of rural farming villages. Therefore, the results generated pertain to rural farming villages. Given that there was no/minimal manipulation present at an entire program scale, we are able to use the program to analyze the rural villages in this data.

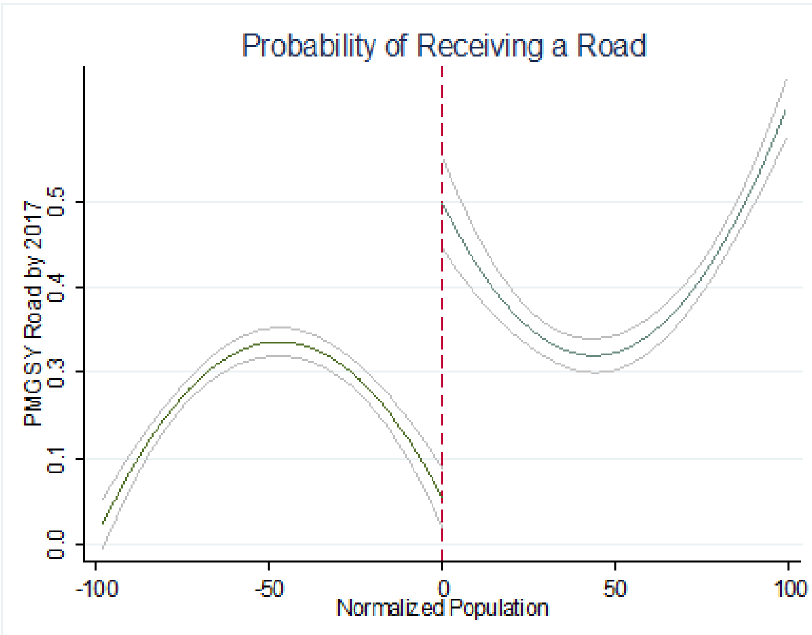
**Figure 1- 3:** Histogram of 2001 population for Eastern Indian villages included in our sample




Note: The figure shows the distribution of village population of the villages included in our sample that have a population between 0 and 1000. The population used in the figure is the recorded population in the 2001 National Population Census. The vertical line represents the program eligibility threshold of 500.

Next, we estimate the first stage regression (equation 2) to determine if there is a discontinuity in the probability of receiving a road at the threshold population of 500 in our sample. The sample of villages used in this study displayed a large and significant jump at the threshold (Figure 1-4); which signifies that villages were more likely to get a road by 2017 if they had a village population of 500 or above in the 2001 National Population Census. This implies that the program eligibility rules were followed by program officials and implementers.[6]

**Figure 1-4**: First stage of RD: the effects of road prioritization on probability of PMGSY road by 2017 in Eastern India




Note: This figure shows the probability of a village getting a PMGSY road by 2017 over the population in recorded in the 2001 National Population Census. The population has been normalized around the population threshold of 500. For this figure villages were included if (1) they fell between the bandwidth of ±100 and (2) were not fully connected in 2001.[7]

Having shown that the running variable of population displays minimal manipulation and that the rules of the program were followed, we can investigate the effects of the program on

[6] Asher and Novosad (2017) also find that program rules were followed at a national-level. They determined that there is a positive effect on the probability of receiving a road when the population threshold is passed.

[7] The bandwidth on the above graph is smaller than the ones presented later in the document because there were a larger number of observations (all villages were used) in the creation of this graph, as we are examining the effects of roads at the population threshold. The graphs pertaining to the specific outcome have a larger bandwidth because less observations were included in the calculation.

women's power in household decision making processes using the econometric models outlined in equations 5 to 8.

## 4.4 Estimation procedure

Once all restrictions and specifications are placed on the data, our sample can be defined as 109 RMS villages that fell within the optimal population bandwidth of 300-700 residents and were not fully connected as of January 2001, which resulted in 5,930 individual responses (with 3,140 male and 2,790 female responses).

Equation 3 and 4 are estimated through the use of a two-stage least squared (2SLS) instrumented variable approach; where the *newroads* variable is instrumented with $pop_v > T$. The first stage of the 2SLS estimates the *newroad* as a function of population, while in the second stage we instrument the *newroad* with population to estimate the effect of the road on empowerment outcomes.

The additional specifications outlined in equations 5 to 8 are also instrumented using the same approach. The goal of our estimation strategy is to estimate the parameter of $\gamma_1$ which can be interpreted at the effect of the PMGSY road program on women's empowerment outcomes.

The results are displayed in two ways. Firstly we provide a depiction of the actual values of each outcome found in the data by means of a local polynomial graph. The graph provides the frequency of the outcome before and after the threshold. Secondly, we provide the estimated results of the outlined models.

## 4.5 Variable definitions and hypothesis

Table 1-3 provides the definitions for the variables used in the analysis and their predicted signs. Each of the all areas of power are expected to increase under the presence of a road due to greater access to resources, services, and markets. This is largely due to, as defined above, roads influence three mean mechanism (shifts in preferences, power, and budget constraint). Overall, we hypothesize a positive shift in *women's overall power* under the presence of a road because all three identified mechanisms will shift causing an increase in decision making abilities of women, relative to men. Women' role in production based decision is believed to be positively influenced by a road largely due to a shifts in preferences, thus changing the households' production practices and a relaxation of the budget constraint from an increases income. While women's decision making abilities in consumption and off-farm labour increase in villages with a road due to shift directly in women's power; thus allowing women's preferences to more heavily influence household decision. Similarly, women's power in credit and land markets is also believed to increase due to power shifts caused by the road.

**Table 1-3:** Definitions and predicted signs for variables included in 2SLS (RD) models

| | Variable Definition | Maximum value | Minimum value | Predicted Sign |
|---|---|---|---|---|
| Population ($pop$) | Village population recorded in the 2001 National Population Census | 0 | 1000 | |
| Population Greater ($pop_v > T$) | Binary variable for if village population is greater then the population threshold of 500 in 2001; where 0 = lower then 500 and 100 = above 500 | 0 | 100 | |
| Connection 2001 | Binary variable for village connection status in 2001, recorded at the start of the program; where 0 = no/ some connection and 100 = full connection | 0 | 100 | |
| Connection 2017 ($newroad$) | Binary variable for village connection status in 2017, recorded at the start of the program; where 0 = no/ some connection and 100 = full connection | 0 | 100 | + |
| *Women's overall power* | Modified A-WAEJ index for the domains of production, income, resources, and leadership; where 0 = not empowered in any domain, and 100 = empowered in all domains (25, 50, 75 are values taken if some empowerment) | 0 | 100 | + |
| *Production mix and output* | Participation in decision about the selection of crop and variety, crop planting/ sowing activities, food and cash crop farming, livestock raising, fishing/ fishpond cultivation; where 0 = no involvement in decisions, and 100 = some/all involvement in decisions | 0 | 100 | + |
| *Marketable surplus* | Participation in decision about the use of production (amount of harvest saved for household consumption, sold, stored, used as animal feed…); where 0 = no involvement in decisions, and 100 = some/all involvement in decisions | 0 | 100 | + |
| *Own-farm labor supply* | Participation in decision making about household labour (who in | 0 | 100 | + |

| | | | | |
|---|---|---|---|---|
| | family works on farm, where they work, and when); where 0 = no involvement in decisions, and 100 = some/all involvement in decisions | | | |
| *Off-farm labor supply* | Participation in decision making about wage and salary employment; where 0 = no involvement in decisions, and 100 = some/all involvement in decisions | 0 | 100 | + |
| *Household expenditures* | Participation in decision making about major household expenditures (land, motorbikes), minor household expenditure (daily food and household needs), and children education (whether to send to school and where) ; where 0 = no involvement in decisions, and 100 = some/all involvement in decisions | 0 | 100 | + |
| *Family planning* | Participation in decision making about whether or not to use family planning to space/limit births in the household; where 0 = no involvement in decisions, and 100 = some/all involvement in decisions | 0 | 100 | + |
| *Land ownership* | Ownership of agricultural land, house or other structures/land either jointly or solely; where 0 = no ownership and 100 = joint or sole ownership | 0 | 100 | + |
| *Access to credit* | Made decisions to borrow from any source of credit (formal, informal, NGO, friend/ relative, group microfinance) as the main or secondary decision maker; where 0 = no involvement in decisions, and 100 = some/all involvement in decisions | 0 | 100 | + |

Note: The table provides the definition, rang, and predicted sign of the variables that are used in this analysis, as it relates to this study.

## 5. Results

In this section, we describe and discuss the main findings of the analysis and the robustness of the results. In total we examine 9 outcomes which represent women's power. For each outcome: first we present a purely descriptive graph based on local polynomial regression which shows the break in the outcome at the population threshold (thus, the size of the break visually depicts the causal impact of roads on women's power in a specific dimension); next, we present the econometric estimates of *women's total power* and the eight breakdown components estimated using equation 5 to 8 (baseline and the variations based on interaction and distance terms). Over all, majority of the regressions perform well in all models, as seen in the overall fit of the model (F-statistic)[8] (table 1-4 to 1-12)

### 5.1 Infrastructure and *women's overall power*

We first examine the model with *women's overall power* as the dependent variable (table 1-4). We find striking evidence women's power in the household agricultural decision making process (*women's overall power)* decreases under the presence of a road. Figure 1-5 graphically depicts the change in *women's overall power* in our sample; the x-axis is the normalized 2001 village population, the y-axis is *women's overall power* (the outcome variable), and the dotted vertical line represents the PMGSY village population threshold of 500. The graph shows that villages above the threshold display a lower level of *women's overall power.*

This result is consistent with the estimations generated via the models outlined in equations 5 to 8 (table 1-4). Under the specifications of the baseline model, connection (through mean of rural roads) was found to decrease *women's overall power* by 87.6% (model 1, row 1).

[8] We were unable to obtain $R^2$ values from the two stage regression discontinuity procedures in STATA and hence, we rely on the F-test of overall significance to validate the models.

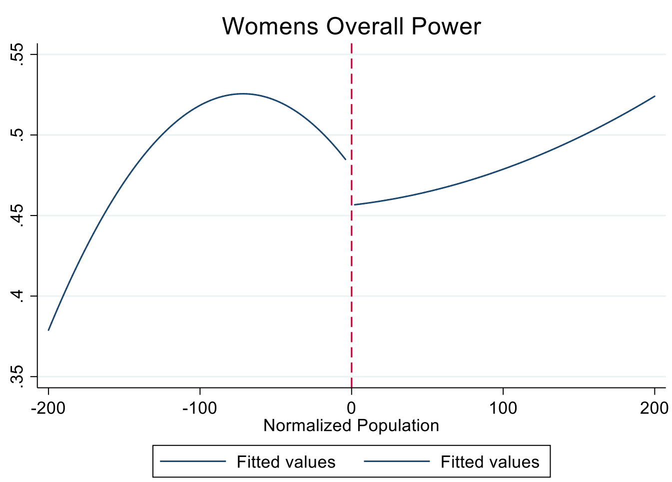
Additionally, the effect of population is also strongly significant in this model (model 1, row 2); where *women's overall power* increases by 4.7% for every 100 unit increase in population.

Surprisingly, we find that the decrease in *women's overall power* is amplified when extending the model to include interaction variables. In the extended model, we observed a decrease of 140% in *women's overall power* (model 3, row 1). With respect to the interaction itself, we find that the interaction between village population and if the village was eligible for the PMGSY program increases *women's overall power* by 65.5% (model 3, row 3). This result can be interpreted as an increase of 65.5% in *women's overall power* for every 100 unit increase in village population when villages are above the village threshold, with the effect lessening in very large villages (model 3, row 4). While the inclusion of difference variable negates the significance of connection status on *women's overall power*. This can potentially be attributed to the fact the difference variables display forms of multicollinearity with other independent variables. The addition of interaction and difference variables allow us to capture non-linearities in the infrastructure – power relationship. Thus, the effects of connection on *women's overall power* is observed to be negative, but the magnitude varies depending on specification.

The drop in *women's overall power* may correspond with a number of factors. This result while shocking, could indicate that roads have opened up access to jobs in towns and employment programs for women. Recent evidence has shown that increases in connectivity often lead to a shift in occupational livelihoods (Asher and Novosad 2017; Bryan, Chowdury and Mobarak 2014; Morten et al. 2018). While, other explanations may suggest a transition of power towards men, caused by women moving out of agriculture. A result consistent with other studies conducted in India that have shown an outward movement of women from agriculture, especially when connection/ transport infrastructure has been introduced in the region. (Pattison 2017; Veettil et al. 2016; Asher and Novosad 2015; Asher and Novosad 2017).

However, this drop in *women's overall power* can mask nuances in other areas of women's power in the household decision making process. Therefore, breakdown the overall measure into several disaggregated measures within four broad dimensions of women's household decision making. In the following section we will explore the effects of the road on household production, household consumption, labour markets, and access to financial and land market. These additional variables will provide for a deeper understanding of how women's power have transformed under the presence of a road; either directly through access or indirectly through other services and institutions that are now accessible to them.

**Figure 1-5**: Regression discontinuity of *women's overall power* over normalized village population, Eastern India, 2016




Note: The above descriptive graph (local average polynomials) present a discontinuity in the fitted values of the *women's overall power* at the population threshold of 500. The y-axis is the frequency of *women's overall power (outcome)*, while the x-axis is the normalized population (normalized to the threshold). The red dotted line depicts the threshold population under the PMSGY program. Villages included in the graph are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Table 1-4**: Results for 2SLS models depicting the fuzzy RD for *overall women's power,* Eastern India, 2016

| | (1)<br>Baseline | (2)<br>Baseline + Difference terms | (3)<br>Baseline + Interaction terms | (4)<br>Combined |
|---|---|---|---|---|
| **Connection Status** | | | | |
| (*newroad)* | -87.624*** | -14.721 | -140.963*** | -396.354 |
| | (21.863) | (21.872) | (34.940) | (448.427) |
| **Normalized Population** | | | | |
| $(pop_v - T)$ | 471.158*** | -382.745* | 209.199 | 24,995.109 |
| | (99.442) | (195.461) | (224.563) | (34,412.117) |
| **Difference$^2$** | | | | |
| $(pop_v - T^2)$ | | -0.557 | | 258.441 |
| | | (0.530) | | (347.138) |
| **Difference$^3$** | | | | |
| $(pop_v - T^3)$ | | 0.022*** | | 0.737 |
| | | (0.004) | | (0.961) |
| **Interaction** | | | | |
| $(\{pop_v > T\} * (pop_v - T))$ | | | 6,550.489*** | -27,497.298 |
| | | | (2,272.543) | (45,606.706) |
| **Interaction$^2$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^2)$ | | | -92.129*** | -271.532 |
| | | | (26.628) | (268.994) |
| **Interaction$^3$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^3)$ | | | 0.339*** | -0.572 |
| | | | (0.091) | (1.143) |
| **Constant** | 69.074*** | 52.764*** | 75.499*** | 172.772 |
| | (5.187) | (4.611) | (6.434) | (154.745) |
| **F-Statistic** | 11.239 | 21.339 | 5.718 | 0.641 |
| **Prob> F** | 0.000 | 0.000 | 0.000 | 0.7219 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results for *overall women's power* (dependent variable). Where column 1 to 4 represent equation 5 to 8 respectively. The discontinuity is represented by the connection status variable, which shows the proportional shift in decision making abilities in the households included in our analysis. All variables, with the exception of the outcome, have been scaled by 10,000. All estimates standard errors are reported below. Villages included in the sample are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

## 5.2 Infrastructure and women's power over specific household decisions

The results generated through each domain are consistent across models and indicate that different areas of household decision making experience a distinct effects under the presence of a road. Taken together, the effects depict the overall influence a road has on household decisions in the predefined categories of household production, household consumption, labour markets, and access of financial and land markets.

Decisions pertaining to household production are comprised of three measures: *production mix and output* (selection of crop, selection of variety, crop planting activities, livestock raising), *marketable surplus* (use of production – consumption, sold, stored) and, and *own-farm labor supply* (household labour on own farm). All of the measures outlined significantly decreased under the presence of a road. Similarly, to the findings of *women's overall power*, the graphs pertaining to *production mix and output*, *marketable surplus*, and *own-farm labor supply* all displayed a drop in power in villages above the road (Figure 1-6).

With respect to the first measure, *production mix and output,* we observed a drop in decision making power of 27.6%, with the effect ranging from -2.0% to -140.4% under different model specifications (Table 1-5, row 1). This result shows that women's bargaining positions for production and output decisions has dropped significantly with the presence of a road. We find a similar drop in *marketable surplus* decision making power. *Marketable surplus'* decreased by 20.8% under the presence of a road, and varied from -107.4% to -192.6% depending on specifications (Table 1-6, row 1). Lastly, *own-farm labor supply* displayed the smallest road effect of the household production measures. *Own-farm labor supply* decision making power decreased by 16.1% under the presence of a road, and ranged from -60.1% to -142.3% given model specifications (Table 1-7, row 1).

Overall, women experience a lower degree of power in decisions regarding production. Therefore, household production may be a significant factor driving down the aggregate index, but this effect may not be illustrative of all decision making effects experienced by women under the presence of a road.

In this study, we also consider effects on consumption, employment, and markets to develop a well rounded understanding of the shifts in women's power with a road. As previously stated, household consumption is comprised of *household expenditures*, *family planning,* and *off-farm labor supply* which refers to decision about individual wage and salary employment, and financial and land market specifically pertaining to decisions over *access to credit* and *land ownership*. Unlike the downward trend observed in decisions centered on household production, women's power in these areas increased under the presence of a road. Thus, women may potentially exhibit a greater sense of authority and autonomy in the decision-making process in these areas in villages with a road.

Contrary to the results observed in household production, both measures of household consumption experienced a positive effect from the presence of a road in the village. In the graphical depiction of *household expenditures* and *family planning* we see a positive shift in decision making once villages surpass the village threshold population of 500 (Figure 1-7). *Household expenditures* decision making power increased 19.0% to 43.4% depending on specification (Table 1-8). Moreover, decisions regarding *family planning* increased by 27.7% under the presence of a road (Table 1-9). Both areas display a positive effect, which may be attributed to an increase in women's autonomy and decision-making abilities with respect to household consumption.

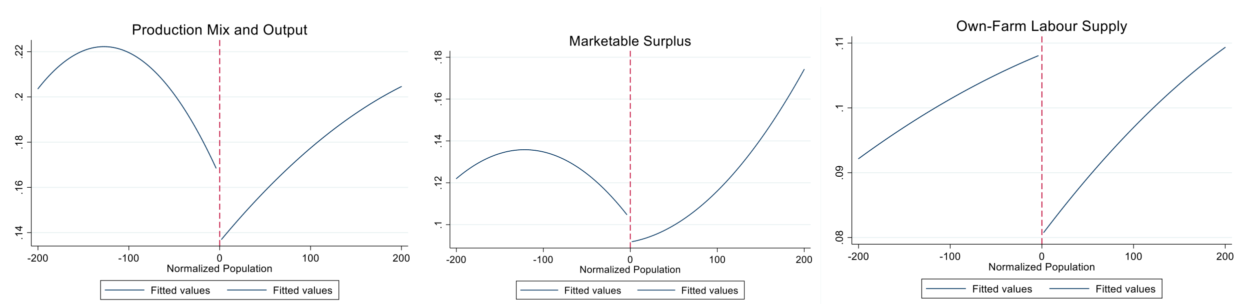
The addition of a road in a village primarily impacts access and connection, labour and employment opportunities are heavily impacted by such shifts. Therefore, in our analysis we also include *off-farm labour supply* to gain insights into this effect. Graphically, we observe an increase in *off- farm labour supply* decisions in villages that are larger then 500 residents (Figure 1-7). When examining the estimates generated through the models, we find mixed results (Table 1-10). As seen in the graph, *off-farm labour supply* decision making power increases by 24.2% under the specifications outlined in model 2 (model 2, row 1). Whereas when examining the effect of a road on *off-farm labour supply* decisions using model 3, we find a drop in power of 80.8% (model 3, row 1). This may be credited to other linearities present in the infrastructure-power relationship.

Lastly, we consider market effects by including the outcomes *access to credit* and *land ownership* in our analysis. As observed in the other non-production based decision measure, both *access to credit,* and *land ownership* displayed a positive jump at the village population threshold (Figure 1-8). With respect to the models run, both mirrored the positive results seen in the graph (Table 1-11 and 1-12). The effects of roads on *land ownership* was estimated to be 20.0% (model 1, row 1). While, road were also was estimated to positively impact *access to credit* by over 38.0%, and the effect is increased to 74.2% to 96.8% depending on model specifications (model 2 and 3, row 1).

As observed in *women's overall power*, non-linearities continue to play a significant roles in explaining the effect of a road on the eight disaggregated measures. Specifically, we find that household production measures were largely influenced by the addition of interactions in the model, while other measures were more intertwined with the added difference variables.

All in all, it can be concluded that the effect of roads differs in different areas of smallholder decision making. Women's decision-making abilities and power do shift under the presence of a road. In the rural Indian villages examined in this study we observed a decrease in household production decision-making, signifying a prevalent negative shift in women's participation in household production decision making; which may be driven by a shift of women's out of agriculture. At the same time, women have experienced empowerment through an increased sense of autonomy in other areas including household consumption, labour supply, and land and financial markets. The shifts in women's empowerment are potentially echoed in the household decision making process and bargaining, where women's preferences play a role in household outcomes.

**Figure 1-6**: Regression discontinuity of *production mix and outputs* (left), *marketable surplus* (middle), and *own-farm labour supply* (right) over normalized village population, Eastern India, 2016




Note: The above descriptive graph (local average polynomials) present a discontinuity in the fitted values of the *production mix and outputs* (left), *marketable surplus* (middle), and *own-farm labour supply* (right) at the population threshold of 500. The y-axis is the frequency of production mix and outputs (left), marketable surplus (middle), and off-farm labour supply (right) (outcome), while the x-axis is the normalized population (normalized to the threshold). The red dotted line depicts the threshold population under the PMSGY program. Villages included in the graph are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Table 1-5**: Results for 2SLS models depicting the fuzzy RD for *production mix and outputs,* Eastern India, 2016

| | (1) Baseline | (2) Baseline + Difference terms | (3) Baseline + Interaction terms | (4) Combined |
|---|---|---|---|---|
| **Connection Status** | | | | |
| (*newroad*) | -27.364*** | -13.38 | -2.006*** | -140.356** |
| | (9.523) | (14.279) | (0.705) | (65.632) |
| **Normalized Population** | | | | |
| $(pop_v - T)$ | 1.912 | -230.553 | -5.838*** | -3014.459** |
| | (51.756) | (155.348) | (2.027) | (1338.1) |
| **Difference$^2$** | | | | |
| $(pop_v - T^2)$ | | 1.041*** | | -26.577* |
| | | (0.302) | | (14.918) |
| **Difference$^3$** | | | | |
| $(pop_v - T^3)$ | | 0.008** | | -0.077* |
| | | (0.004) | | (0.046) |
| **Interaction** | | | | |
| $(\{pop_v > T\} * (pop_v - T))$ | | | 135.158*** | 14254.912*** |
| | | | (44.257) | (3446.135) |
| **Interaction$^2$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^2)$ | | | -1.430*** | -97.854** |
| | | | (0.460) | (42.526) |
| **Interaction$^3$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^3)$ | | | 0.004*** | 0.467*** |
| | | | (0.001) | (0.116) |
| **Constant** | 27.120*** | 21.660*** | 0.589*** | 41.268*** |
| | (2.749) | (4.027) | (0.148) | (15.698) |
| **F-Statistic** | 11.836 | 9.808 | 3.127 | 4.458 |
| **Prob> F** | 0.000 | 0.000 | 0.000 | 0.008 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results for *production mix and outputs* (dependent variable). Where column 1 to 4 represent equation 5 to 8 respectively. The discontinuity is represented by the connection status variable, which shows the proportional shift in decision making abilities in the households included in our analysis. All variables, with the exception of the outcome, have been scaled by 10,000. All estimates standard errors are reported below. Villages included in the sample are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Table 1-6**: Results for 2SLS models depicting the fuzzy RD for *marketable surplus,* Eastern India, 2016

| | (1) Baseline | (2) Baseline + Difference terms | (3) Baseline + Interaction terms | (4) Combined |
|---|---|---|---|---|
| **Connection Status** | | | | |
| (*newroad)* | -20.795*** | -8.247 | -192.649*** | -107.367** |
| | (7.867) | (11.855) | (66.022) | (51.095) |
| **Normalized Population** | | | | |
| $(pop_v - T)$ | 92.109** | -122.87 | -489.900*** | -4386.664*** |
| | (42.756) | (128.969) | (189.955) | (1041.716) |
| **Difference$^2$** | | | | |
| $(pop_v - T^2)$ | | 1.149*** | | -45.946*** |
| | | (0.250) | | (11.614) |
| **Difference$^3$** | | | | |
| $(pop_v - T^3)$ | | 0.007** | | -0.142*** |
| | | (0.003) | | (0.036) |
| **Interaction** | | | | |
| $(\{pop_v > T\} * (pop_v - T))$ | | | 13865.489*** | 15369.002*** |
| | | | (4146.580) | (2682.831) |
| **Interaction$^2$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^2)$ | | | -150.867*** | -78.636** |
| | | | (43.134) | (33.107) |
| **Interaction$^3$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^3)$ | | | 0.480*** | 0.542*** |
| | | | (0.131) | (0.090) |
| **Constant** | 18.509*** | 13.308*** | 50.015*** | 25.072** |
| | (2.271) | (3.344) | (13.911) | (12.221) |
| **F-Statistic** | 3.493 | 7.888 | 3.499 | 8.363 |
| **Prob> F** | 0.030 | 0.000 | 0.004 | 0.000 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results *marketable surplus* (dependent variable). Where column 1 to 4 represent equation 5 to 8 respectively. The discontinuity is represented by the connection status variable, which shows the proportional shift in decision making abilities in the households included in our analysis. All variables, with the exception of the outcome, have been scaled by 10,000. All estimates standard errors are reported below. Villages included in the sample are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

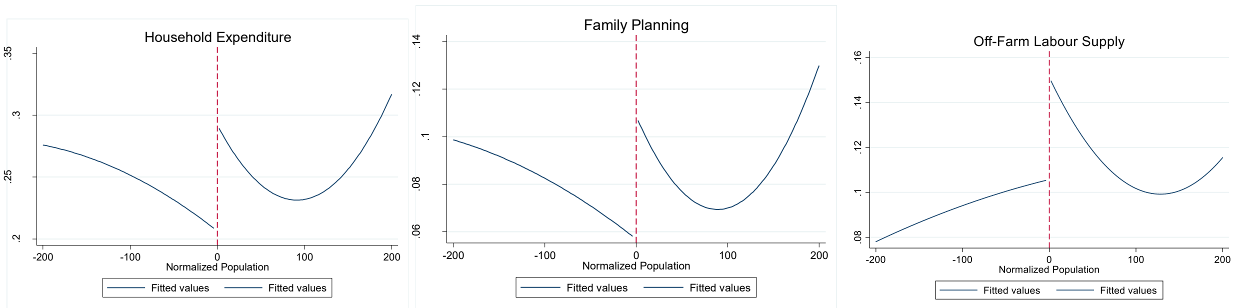
**Table 1-7:** Results for 2SLS models depicting the fuzzy RD for *own-farm labour supply,* Eastern India, 2016

| | (1) Baseline | (2) Baseline + Difference terms | (3) Baseline + Interaction terms | (4) Combined |
|---|---|---|---|---|
| **Connection Status** | | | | |
| (*newroad*) | -16.133** | -20.777* | -142.286*** | -60.068* |
| | (6.974) | (10.873) | (49.527) | (34.610) |
| **Normalized Population** | | | | |
| $(pop_v - T)$ | 81.756** | 142.685 | -234.206 | -4383.118*** |
| | (37.904) | (118.286) | (142.496) | (705.613) |
| **Difference$^2$** | | | | |
| $(pop_v - T^2)$ | | 0.200 | | -51.442*** |
| | | (0.230) | | (7.867) |
| **Difference$^3$** | | | | |
| $(pop_v - T^3)$ | | -0.001 | | -0.165*** |
| | | (0.003) | | (0.024) |
| **Interaction** | | | | |
| $(\{pop_v > T\} * (pop_v - T))$ | | | 9897.997*** | 11739.639*** |
| | | | (3110.58) | (1817.232) |
| **Interaction$^2$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^2)$ | | | -108.792*** | -32.009 |
| | | | (32.357) | (22.425) |
| **Interaction$^3$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^3)$ | | | 0.341*** | 0.429*** |
| | | | (0.099) | (0.061) |
| **Constant** | 14.495*** | 15.539*** | 38.887*** | 14.840* |
| | (2.013) | (3.067) | (10.436) | (8.278) |
| **F-Statistic** | 2.79 | 1.465 | 2.542 | 11.397 |
| **Prob> F** | 0.015 | 0.210 | 0.026 | 0.000 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

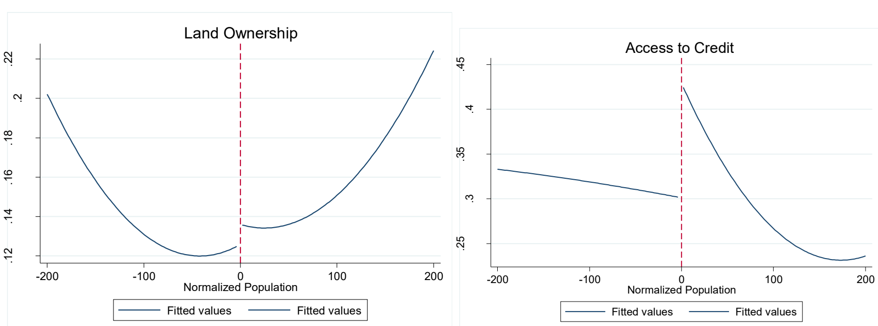
Note: The table presents the instrumented two stage regression results *own-farm labour supply* (dependent variable). Where column 1 to 4 represent equation 5 to 8 respectively. The discontinuity is represented by the connection status variable, which shows the proportional shift in decision making abilities in the households included in our analysis. All variables, with the exception of the outcome, have been scaled by 10,000. All estimates standard errors are reported below. Villages included in the sample are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Figure 1-7**:Regression discontinuity of *household expenditures* (left), *family planning* (middle), and *off-farm labour supply* (right) over normalized village population, Eastern India, 2016




Note: The above descriptive graph (local average polynomials) present a discontinuity in the fitted values of the *household expenditures* (left), *family planning* (middle), and *off-farm labour supply* (right) at the population threshold of 500. The y-axis is the frequency of production mix and outputs (left), marketable surplus (middle), and off-farm labour supply (right) (outcome), while the x-axis is the normalized population (normalized to the threshold). The red dotted line depicts the threshold population under the PMSGY program. Villages included in the graph are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Figure1-8:** Regression discontinuity of *land ownership* (left), and *access to credit* (right) over normalized village population, Eastern India, 2016




Note: The above descriptive graph (local average polynomials) present a discontinuity in the fitted values the *land ownership* (left), and *access to credit* (right) at the population threshold of 500. The y-axis is the frequency of production mix and outputs (left), marketable surplus (middle), and off-farm labour supply (right) (outcome), while the x-axis is the normalized population (normalized to the threshold). The red dotted line depicts the threshold population under the PMSGY program. Villages included in the graph are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Table 1-8:** Results for 2SLS models depicting the fuzzy RD for *household expenditures,* Eastern India, 2016

| | (1) Baseline | (2) Baseline + Difference terms | (3) Baseline + Interaction terms | (4) Combined |
|---|---|---|---|---|
| **Connection Status** | | | | |
| (*newroad)* | 19.010* | 43.441** | 1.019 | 63.919 |
| | (10.428) | (17.419) | (32.251) | (48.766) |
| **Normalized Population** | | | | |
| $(pop_v - T)$ | -110.243* | -498.279*** | -329.190*** | -3048.264*** |
| | (56.676) | (189.509) | (92.791) | (994.228) |
| **Difference²** | | | | |
| $(pop_v - T^2)$ | | 1.212*** | | -31.063*** |
| | | (0.368) | | (11.085) |
| **Difference³** | | | | |
| $(pop_v - T^3)$ | | 0.012** | | -0.094*** |
| | | (0.005) | | (0.034) |
| **Interaction** | | | | |
| $(\{pop_v > T\} * (pop_v - T))$ | | | 2837.491 | 3791.404 |
| | | | (2025.548) | (2560.531) |
| **Interaction²** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^2)$ | | | -38.027* | 12.423 |
| | | | (21.070) | (31.598) |
| **Interaction³** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^3)$ | | | 0.146** | 0.180** |
| | | | (0.064) | (0.086) |
| **Constant** | 19.810*** | 11.126** | 21.312*** | 2.916 |
| | (3.010) | (4.913) | (6.796) | (11.664) |
| **F-Statistic** | 1.979 | 5.536 | 8.674 | 5.253 |
| **Prob> F** | 0.138 | 0.000 | 0.000 | 0.000 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results *household expenditure* (dependent variable). Where column 1 to 4 represent equation 5 to 8 respectively. The discontinuity is represented by the connection status variable, which shows the proportional shift in decision making abilities in the households included in our analysis. All variables, with the exception of the outcome, have been scaled by 10,000. All estimates standard errors are reported below. Villages included in the sample are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Table 1-9:** Results for 2SLS models depicting the fuzzy RD for *family planning,* Eastern India, 2016

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Baseline | Baseline + Difference terms | Baseline + Interaction terms | Combined |
| **Connection Status** | | | | |
| (*newroad*) | 10.096 | 27.713** | 15.576 | 18.929 |
| | (6.584) | (11.017) | (21.395) | (26.804) |
| **Normalized Population** | | | | |
| $(pop_v - T)$ | -55.926 | -334.745*** | -166.572*** | -180.659 |
| | (35.787) | (119.858) | (61.556) | (546.482) |
| **Difference$^2$** | | | | |
| $(pop_v - T^2)$ | | 0.841*** | | 0.729 |
| | | (0.233) | | (6.093) |
| **Difference$^3$** | | | | |
| $(pop_v - T^3)$ | | 0.009*** | | 0.004 |
| | | (0.003) | | (0.019) |
| **Interaction** | | | | |
| $(\{pop_v > T\} * (pop_v - T))$ | | | 517.327 | 437.306 |
| | | | (1343.722) | (1407.407) |
| **Interaction$^2$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^2)$ | | | -9.945 | -9.641 |
| | | | (13.978) | (17.368) |
| **Interaction$^3$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^3)$ | | | 0.049 | 0.041 |
| | | | (0.043) | (0.047) |
| **Constant** | 5.502*** | -0.713 | 3.029 | 2.048 |
| | (1.901) | (3.107) | (4.508) | (6.411) |
| **F-Statistic** | 1.324 | 6.254 | 7.000 | 4.882 |
| **Prob> F** | 0.266 | 0.000 | 0.000 | 0.000 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results *family planning (*dependent variable). Where column 1 to 4 represent equation 5 to 8 respectively. The discontinuity is represented by the connection status variable, which shows the proportional shift in decision making abilities in the households included in our analysis. All variables, with the exception of the outcome, have been scaled by 10,000. All estimates standard errors are reported below. Villages included in the sample are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Table 1-10:** Results for 2SLS models depicting the fuzzy RD for *off-farm labour supply,* Eastern India, 2016

| | (1) Baseline | (2) Baseline + Difference terms | (3) Baseline + Interaction terms | (4) Combined |
|---|---|---|---|---|
| **Connection Status** | | | | |
| ($newroad$) | 8.479 | 24.254** | -80.841** | -31.589 |
| | (7.119) | (11.831) | (32.151) | (28.530) |
| **Normalized Population** | | | | |
| ($pop_v - T$) | 42.421 | -165.716 | -38.024 | -2477.928*** |
| | (38.694) | (128.710) | (92.501) | (581.673) |
| **Difference²** | | | | |
| ($pop_v - T^2$) | | -0.640** | | -29.987*** |
| | | (0.250) | | (6.485) |
| **Difference³** | | | | |
| ($pop_v - T^3$) | | 0.005 | | -0.095*** |
| | | (0.003) | | (0.020) |
| **Interaction** | | | | |
| ($\{pop_v > T\} * (pop_v - T)$) | | | 7666.696*** | 8724.444*** |
| | | | (2019.234) | (1498.038) |
| **Interaction²** | | | | |
| ($\{pop_v > T\} * (pop_v - T)^2$) | | | -94.587*** | -49.420*** |
| | | | (21.005) | (18.486) |
| **Interaction³** | | | | |
| ($\{pop_v > T\} * (pop_v - T)^3$) | | | 0.310*** | 0.359*** |
| | | | (0.064) | (0.050) |
| **Constant** | 7.746*** | 4.144 | 26.644*** | 12.239* |
| | (2.055) | (3.337) | (6.774) | (6.824) |
| **F-Statistic** | 6.937 | 4.961 | 9.669 | 16.206 |
| **Prob> F** | 0.001 | 0.001 | 0.000 | 0.000 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results *off-farm labour supply* (dependent variable). Where column 1 to 4 represent equation 5 to 8 respectively. The discontinuity is represented by the connection status variable, which shows the proportional shift in decision making abilities in the households included in our analysis. All variables, with the exception of the outcome, have been scaled by 10,000. All estimates standard errors are reported below. Villages included in the sample are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Table 1-11:** Results for 2SLS models depicting the fuzzy RD for *land ownership,* Eastern India, 2016

| | (1) Baseline | (2) Baseline + Difference terms | (3) Baseline + Interaction terms | (4) Combined |
|---|---|---|---|---|
| **Connection Status** | | | | |
| (*newroad)* | 20.016** | 4.018 | -23.487 | -5.630 |
| | (8.603) | (12.852) | (27.642) | (32.833) |
| **Normalized Population** | | | | |
| $(pop_v - T)$ | -65.718 | 100.650 | -486.229*** | -2155.417*** |
| | (46.758) | (139.824) | (79.530) | (669.390) |
| **Difference$^2$** | | | | |
| $(pop_v - T^2)$ | | 2.149*** | | -25.171*** |
| | | (0.272) | | (7.463) |
| **Difference$^3$** | | | | |
| $(pop_v - T^3)$ | | -0.002 | | -0.091*** |
| | | (0.004) | | (0.023) |
| **Interaction** | | | | |
| $(\{pop_v > T\} * (pop_v - T))$ | | | 4078.699** | 5246.757*** |
| | | | (1736.074) | (1723.943) |
| **Interaction$^2$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^2)$ | | | -40.642** | -9.967 |
| | | | (18.059) | (21.274) |
| **Interaction$^3$** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^3)$ | | | 0.139** | 0.213*** |
| | | | (0.055) | (0.058) |
| **Constant** | 9.547*** | 11.086*** | 14.418** | 9.196 |
| | (2.484) | (3.625) | (5.824) | (7.853) |
| **F-Statistic** | 3.047 | 19.063 | 15.395 | 14.798 |
| **Prob> F** | 0.048 | 0.000 | 0.000 | 0.000 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results *land ownership* (dependent variable). Where column 1 to 4 represent equation 5 to 8 respectively. The discontinuity is represented by the connection status variable, which shows the proportional shift in decision making abilities in the households included in our analysis. All variables, with the exception of the outcome, have been scaled by 10,000. All estimates standard errors are reported below. Villages included in the sample are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

**Table 1-12:** Results for 2SLS models depicting the fuzzy RD for *access to credit,* Eastern India, 2016

| | (1)<br>Baseline | (2)<br>Baseline + Difference terms | (3)<br>Baseline + Interaction terms | (4)<br>Combined |
|---|---|---|---|---|
| **Connection Status** | | | | |
| (*newroad)* | 38.047*** | 74.175*** | 96.786** | 67.856 |
| | (10.912) | (18.921) | (43.347) | (47.08) |
| **Normalized Population** | | | | |
| $(pop_v - T)$ | -386.964*** | -855.715*** | 58.679 | 1668.577* |
| | (59.308) | (205.848) | (124.715) | (959.866) |
| **Difference²** | | | | |
| $(pop_v - T^2)$ | | -1.732*** | | 20.835* |
| | | (0.400) | | (10.702) |
| **Difference³** | | | | |
| $(pop_v - T^3)$ | | 0.011** | | 0.069** |
| | | (0.005) | | (0.033) |
| **Interaction** | | | | |
| $(\{pop_v > T\} * (pop_v - T))$ | | | -3350.271 | -4148.321* |
| | | | (2722.435) | (2472.035) |
| **Interaction²** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^2)$ | | | 16.312 | -13.439 |
| | | | (28.319) | (30.506) |
| **Interaction³** | | | | |
| $(\{pop_v > T\} * (pop_v - T)^3)$ | | | -0.026 | -0.068 |
| | | | (0.086) | (0.083) |
| **Constant** | 19.208*** | 11.334** | 11.243 | 19.705* |
| | (3.150) | (5.337) | (9.134) | (11.261) |
| **F-Statistic** | 26.065 | 14.991 | 11.38 | 10.982 |
| **Prob> F** | 0.000 | 0.000 | 0.000 | 0.000 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results *access to credit* (dependent variable). Where column 1 to 4 represent equation 5 to 8 respectively. The discontinuity is represented by the connection status variable, which shows the proportional shift in decision making abilities in the households included in our analysis. All variables, with the exception of the outcome, have been scaled by 10,000. All estimates standard errors are reported below. Villages included in the sample are not fully connected as of the 2001 connection status and fell within the optimal bandwidth of ±200.

### 5.3 Additional findings and robustness checks

In this section we examine the robustness and credibility of the results generated in 5.1 and 5.2. We begin by showing that the threshold of 500 plays a significant role in the determination of a road, as compared to other random thresholds. Additionally, we test the model using other village characteristics to examine if other factors are driving the shifts in power.

To show the validity and importance of the threshold for the results, we run the 2SLS model at non-threshold population levels for the outcome of *overall women's power*. In order to conduct this test, we use unconnected villages with a population between 0 and 1000 in the 2001 national population census. We observe that at these thresholds there is little to no evidence that there is a discontinuity in *overall women's power* (Table 1-13). In table 1-13, it can be seen that only at the 500 population threshold there is a significant effect on overall women's power, thus showing that at the population of 500 there is a force (the PMGSY program) driving an effect for villages above and below the threshold.

Other factors that may influence our results are the location of the village and other village characteristics. There is potential that the shifts in power have been incorrectly attributed the effects to the road treatment, when in reality the effects are a function of these other characteristics. To test for this, we run the baseline model with additional fixed effects (equation 2* and 3*). Fixed effects allow us to account for unobserved heterogeneity between different groups. Fixed effects were not included in the original model because they are not necessary to identify the treatment effect, rather they are a means to increase efficiency of the generated estimates. Two types of fixed effects will be included in our model, (1) location-oriented fixed effects like State, District, and Tashil,[9] and (2) village-fixed effects for the presence of schools and health centres. Given our new specification, the new model is outlined as followed:

$$newroad_v = \beta_0 + \beta_1\{pop_v > T\} + \beta_2 (pop_v - T) + \lambda_v + \varepsilon \quad (2^*)$$

$$Y_{v,n} = \gamma_0 + \gamma_1 newroad_v + \gamma_2(pop_v - T) + \lambda_v + \varepsilon \quad (3^*)$$

Where $\lambda_v$ represents a vector of fixed effect included, and all other variables are defined as above.

Table 1-14 outlines the location fixed effects model, where it can be concluded that location may play a minor role in determining the magnitude of the connection effect in a village. Specifically, when examining the estimations generated when accounting for State and District level variation, the results were still statistically significant (Table 1-14). Therefore, it can be said that State and District level heterogeneity may need to be considered when looking at *women's overall power*. States and Districts are tremendously diverse in terms of culture, language, landscape, and policies. Moreover, special status villages received slightly adjusted thresholds which may have been influenced by location. For instance, Odisha contains a high number of tribal villages, while both Odisha and West Bengal contain many remote villages, both village types that are labelled as special status under the program.

Additionally, the effects of village characteristics on *women's overall power* were also considered. We created two categories of village characteristics that may influence power, (1) schools and (2) healthcare. Both of which have also been shown to independently increase women's power in a region. The results presented in Table 1-15 indicate that the presence of

---

[9] A Tashil is an administrative division of India denoting a sub-district

health care services influences *women's overall power,* while the presence of schools in a village does not. This result may signify that the shifts in power may not be solely explained by the road per se, rather by health services like dispensaries, and maternity and child welfare centres. The effects associated with health and education services do not diminish the results because the methods used in this study allow for identification. As previously specified, the combination of the use of an RD and the implementation of the PMGSY road program creates counterfactual groups that are statistically equivalent, thus allowing us to account for this finding so some degree.

Another potential flaw in the statistical identification of the road effect presented in this study is the possibility that other policies used the same population threshold as the PMSGY. State and Federal governments are constantly implementing new programs, many of which that can effect women's power. However, in our review of the literature and government programs we did not find any other program that uses the same 500 village population threshold based on the 2001 National Population Census record of the population. If other programs were indirectly correlated with the threshold (e.g. programs that depend on roads to be present) it is unlikely that they are spuriously driving our results. Therefore, the PMGSY program may provide the main effect on women's power, but other programs that rely on roads may effect the magnitude of the total effect.

Through the use of these additional tests, we show that our results are robust and consistent when considering other factors that can effect the impact on women's power. The magnitude of the results may slightly shift under the inclusion of additional covariates, but the overall direction of effect should remain unchanged.

**Table 1-13:** Robustness for 2SLS models depicting the fuzzy RD results at different thresholds for *overall women's power*, Eastern India, 2016

| | (1)<br>Baseline at<br>500 threshold | (2)<br>Baseline at<br>400 threshold | (3)<br>Baseline at<br>300 threshold | (4)<br>Baseline at<br>200 threshold | (5)<br>Baseline at<br>600 threshold | (6)<br>Baseline at<br>700 threshold |
|---|---|---|---|---|---|---|
| **Connection Status** (*newroad)* | -92.516** | -5,209.723 | -2,666.295 | -179.110 | -5,893.676 | -971.145 |
| | (41.259) | (33,821.740) | (27,315.199) | (184.374) | (38,834.035) | (1,711.045) |
| **Normalized Population (500)** $(pop_v - 500)$ | 0.015** | | | | | |
| | (0.006) | | | | | |
| **Normalized Population (400)** $(pop_v - 400)$ | | 0.555 | | | | |
| | | (3.575) | | | | |
| **Normalized Population (300)** $(pop_v - 300)$ | | | 0.287 | | | |
| | | | (2.887) | | | |
| **Normalized Population (200)** $(pop_v - 200)$ | | | | 0.024 | | |
| | | | | (0.020) | | |
| **Normalized Population (600)** $(pop_v - 600)$ | | | | | 0.628 | |
| | | | | | (4.105) | |
| **Normalized Population (700)** $(pop_v - 700)$ | | | | | | 0.108 |
| | | | | | | (0.182) |
| **Constant** | 210.726*** | 1,263.947 | 711.060 | 222.333*** | 1,530.463 | 422.612 |
| | (9.027) | (6,970.929) | (5,341.208) | (34.147) | (8,824.783) | (406.954) |
| **F-Statistic** | 3.060 | 0.010 | 0.010 | 0.930 | 0.010 | 0.200 |
| **Prob> F** | 0.047 | 0.987 | 0.990 | 0.396 | 0.988 | 0.817 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results for *overall women's power* (dependent variable) across different population thresholds for equation 3*. Column 1 is conducted at the PMGSY population threshold of 500, while the other columns are random threshold (Column 2 at 400, Column 3 at 300, Column 4 at 200, Column 5 at 600, Column 6 at 700, and Column 8 at 800. Villages included in the sample are not fully connected as of the 2001 connection status and had a population between 0 – 1000.

**Table 1-14**: Robustness for 2SLS models depicting the fuzzy RD results for *overall women's power* with location fixed effects, Eastern India, 2016

| | (1)<br>Baseline with Tashil fixed effects | (2)<br>Baseline with District fixed effects | (3)<br>Baseline with State fixed effects |
|---|---|---|---|
| **Connection Status (*newroad*)** | -61.993 | -101.674*** | -146.539** |
| | (55.022) | (30.899) | (63.268) |
| **Normalized Population** $(pop_v - T)$ | -0.024** | 0.003 | 0.027*** |
| | (0.011) | (0.005) | (0.008) |
| **Constant** | 201.092*** | 211.659*** | 223.013*** |
| | (11.895) | (6.590) | (13.786) |
| **Number of Tashi** | 210 | | |
| **Number of District** | | 73 | |
| **Number of State** | | | 4 |
| **F-Statistic** | 20.530 | 25.460 | 71.420 |
| **Prob> F** | 0.000 | 000 | 0.000 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results for *overall women's power* (dependent variable) for equation 3* with different location fixed effects. The village population threshold is 500. Column 1 includes village Tashils fixed effects, Column 2 includes village Districts fixed effects, and Column 3 includes village States fixed effects. Villages included in the sample are not fully connected as of the 2001 connection status and had a population between 0 – 1000.

**Table 1-15**: Robustness for 2SLS models depicting the fuzzy RD results for *overall women's power* with village characteristic fixed effects, Eastern India, 2016

| | (1)<br>Baseline with education fixed effects | | (2)<br>Baseline with health fixed effects |
|---|---|---|---|
| **Connection Status** | -63.538 | **Connection Status** | -113.447*** |
| | (50.912) | | (40.980) |
| **Normalized Population** | -0.006 | **Normalized Population** | 0.011 |
| | (0.013) | | (0.008) |
| **Primary School** | 25.850** | **Health Service Provider** | 27.278*** |
| | (10.723) | | (5.953) |
| **Middle School** | 11.728** | **Dispensary** | -18.636*** |
| | (4.677) | | (6.215) |
| **High School** | -20.815 | **Maternity & Child Welfare Services** | 24.836*** |
| | (12.674) | | (9.293) |
| **Intermediary School** | 5.290 | **Primary Health Center** | -22.570** |
| | (17.378) | | (9.196) |
| **Degree Collage** | 42.822 | **Constant** | 212.019*** |
| | (26.999) | | (10.249) |
| **Constant** | 189.278*** | | |
| | (16.922) | | |
| **F-Statistic** | 46.700 | **F-Statistic** | 30.500 |
| **Prob> F** | 0.000 | **Prob> F** | 0.000 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The table presents the instrumented two stage regression results for *overall women's power* (dependent variable) for equation 3* with different village fixed effects. The village population threshold is 500. Column 1 includes village education services fixed effects, and Column 2 includes village health services fixed effects. Villages included in the sample are not fully connected as of the 2001 connection status and had a population between 0 – 1000.

## 6. Discussion & Limitation

The results found in this study hold tremendous importance for understanding the effects of public infrastructure on households' power and dynamics, specifically women's power in rural households. Infrastructure is a large investment that impacts the livelihoods of residents through rural transformations that can be either positive or negative to women's power.

With respect to women's empowerment and bargaining power within the household, our study indicates that infrastructure generated a number of effects for rural households. Firstly, women experience a drop in agricultural decision making power. This drop may signify that women are participating less is household agriculture activities, therefore, reallocating their time and efforts to other resources and employment opportunities brought forth by the road. On the other hand, roads also have the potential to increase the role of men in agriculture, driven by the increase in access to inputs and output markets. The increase in men's power may lead to women being either forced to stay near the homestead or pushed into other sectors. These results are consistent with the findings from the focus groups, where we found that established farmers were becoming more involved in agriculture due to the greater market access and income potential. Women were found to be more active in causal labour, as more options are available to them with the provision of the road. This outward shift of women in agriculture may be perceived as a positive rural transformation (positive transformations are frequently considered when populations shift from rural to urban).

Additionally, we also found that roads benefited women's empowerment off the farm, with the potential that the greater power produces benefits for the women and others in their families. The key idea behind this belief is that women and men display differing preferences;

where women more commonly hold preferences that reflect the needs of the household, especially the needs of children (Duflo 2000). Therefore, increases in household expenditure power may shift household utility by allowing women's preferences to be translated into positive outcomes for the household. For example, in our focus group we found households in connected villages were more likely to spend on children and children education – a preference often attributed to women.

Roads also provide access to government services and programs targeted to women, as well as the ability for women- centered government programs to access the village. Therefore, the positive empowerment effect estimated for the road effect may not be solely caused by the presence of a road, rather the increase in power may have occurred in conjunction with other programs. For example, the rise in family planning decisions may not have occurred strictly through the presence of the road, rather government services and social programs have become accessible due to roads. Roads provide women with the feasibility to attend and participate in self- help and education groups that provide resources on education, legal services, and contraception. In relation to the focus group conducted, we found that villages did experience an increase in available government services and programs in the villages under the presence of a road. Women actively participated in self- help groups that provided information on reproductive health and financial resources, among others.

With respect to the methods and procedure used in this study, other factors may also play a role in the specifics of our findings. The PMGSY data indicate whether or not a village has been sanctioned or approved for a road, yet, in some instances villages may have been recorded as sanctioned, but had not yet received a road as of 2017. This possibility was illuminated by one of the focus groups.  One village was listed as sanctioned in 2017 but by November 2018, nor was the road or construction present in the village. The notion of "missing roads" is the largest political flaw in the PMGSY program (Lehne et al. 2018). Corruption frequently plagues the Indian government, therefore government officials may sanction a road in a village for political motives but villages never receive the roads. We accounted for this in the study by using a fuzzy RD design, as corruption is a form of noncompliance.

Moreover, some effects of a road are not quantified in the data used for this study. Specifically, the presence of a road may effect the marriage market and migration of girls away from their home village. The ability to marry further and maintain a connection/ the ability to access your own family is tremendously important in Indian culture. The findings produced during the focus groups pertaining to marriage markets were beyond the scope of our data, and not quantifiable in this study. Therefore, studies on the effects of infrastructure, empowerment and marriage may be an interesting area to explore in future research.

Migration patterns were directly considered in this study, as this study explicitly focuses on decision making power. In this study we did not include migration, though it was indirectly accounted for in the inclusion of o*ff-farm labour supply.* Migration has the potential to influence the power relations within the household due to shifts in income sources. Asher and Novsad (2017) had shown that roads do impact migration through an outward movement of residents from rural to urban settings.

Lastly, our study did not account for spatial effects of nearby villages with road access to external markets. This may have resulted in an underestimation of our results because villages that do not have a road, may not be entirely without access. Similarly to the results in villages with a direct link-road, nearby roads may also empower women and shift household decision making and power.

## 7. Conclusion

Easily overlooked, access to markets and institutions by paved road is far from a reality for many of the world's rural poor (Asher and Novosad 2017; Asian Development Bank 2018). Residents success/ potential is often constrained by high transportation costs and limited access to markets and services. On an international and national level, recent efforts have been made to remove the obstacles faced by rural communities (OMMAS n.d.; Donaldson 2018; Asher and Novosad 2017). Despite these investments, limited evidence exists on the causal impacts of rural roads.

In this study we estimate the impacts of the Pradhan Mantri Gram Sadak Yojana roads program on women's power, specifically focusing on the decision-making abilities of women in their households. The PMGSY program aimed to provide universal access to rural Indian communities via paved road through the administration of strict program guidelines and rules. Due to the implementation structure of the program, we are able to exploit discontinuities in the probability of receiving a road at the threshold population. We find that road connection impacts women's power through a variety of pathways. More explicitly, we see a drop in women's decision making abilities pertaining to production agriculture, while we observe increases in other areas like employment, non-agriculture household decisions, land ownership and access to credit. Therefore it can be said that roads may be facilitating an outward movement of women in agriculture and into other areas.

Women's empowerment is a pressing issue. It is an issue that has received government support through the implementation of programs and policies aimed at reducing the inequalities faced by women in all walks of life. Such efforts have been both gender-sensitive and gender-neutral in nature, yet the gaps between men and women remain far from negligible. Much of the research currently completed is on the impacts of gender-sensitive measures, as impacts are more direct and well understood. Our study focuses on understanding the impacts associated with gender-neutral interventions, focusing on rural roads and access. Our findings suggest that access to roads impact the empowerment of women through a number of different streams with respect to decision making. Overall, it manifests in a decrease in power over agriculture decisions but an increase in other areas of household decision making.

This paper adds to a growing body of literature on the impacts of public infrastructure development in its own right, as well as on gender equality. Our study is at the crossroads of infrastructure and identifiable effects. To our knowledge it is the first of its kind to use the regression discontinuity method to evaluate how rural roads affect women's power relative to men. We hope that further research will quantify other gender-neutral interventions in order to provide governments and research organizations the foundation and understanding needed to eliminate the gender gap in all aspects of life.

## 8. References

Agénor, P. 2006. "Discussion Paper Series A Theory of Infrastructure-led Development Download paper from : of Infrastructure-Led Development." *Centre for Growth and Business Cycle Research* (083). Available at: http://linkinghub.elsevier.com/retrieve/pii/S0165188910000102.

Aggarwal, S. 2018. "Do rural roads create pathways out of poverty? Evidence from India." *Journal of Development Economics* 133(January):375–395. Available at: https://doi.org/10.1016/j.jdeveco.2018.01.004.

Alderman, H., P.A. Chiappori, L. Haddad, J. Hoddinott, and R. Kanbur. 1995. "Unitary vs Collective Models of the household: Is it time to shift the burden of proof?" *The World Bank Research Observer* 10(1):1–19.

Ali, I., and Z.A. Hatta. 2012. "Women's Empowerment or Disempowerment through Microfinance: Evidence from Bangladesh." *Asian Social Work and Policy Review* 6(2):111–121.

Alkire, S., R. Meinzen-Dick, A. Peterman, A.R. Quisumbing, G. Seymour, and A. Vaz. 2012. "'The Women's Empowerment in Agriculture Index,' Poverty, Health & Nutrition Division, International Food Policy Research Institute, IFPRI Discussion Paper No. 01240, December 2012. http://www.ifpri.org/publication/women-s-empowerment-agriculture-index."

Ambler, K., and A. De Brauw. 2017. "The Impacts of Cash Transfers on Women's Empowerment." *World Bank Group Soical Protection and Labour* (1702).

Asher, S., and P. Novosad. 2017. "Rural Roads and Structural Transformation." Available at: http://www.dartmouth.edu/~novosad/asher-novosad-roads.pdf.

Asher, S., and P. Novosad. 2015. "The Employment Effects of Road Construction in Rural India."

Asian Development Bank. 2018. "Outlook 2018 Update - MAINTAINING STABILITY AMID HEIGHTENED UNCERTAINTY."

Athey, S., and G. Imbens. 2015. "Recursive Partitioning for Heterogeneous Causal Effects." *National Academy of Sciences of the United States of America* 113(27):7353–7360. Available at: http://arxiv.org/abs/1504.01132.

Bell, C. 2010. "Goods, Education and Health: A Combined Model for Evaluating PMGSY."

Bertocchi, G., M. Brunetti, and C. Torricelli. 2014. "Who holds the purse strings within the household? The determinants of intra-family decision making." *Journal of Economic Behavior and Organization* 101(2014):65–86. Available at: http://dx.doi.org/10.1016/j.jebo.2014.02.012.

Besley, T., and Burgess. 2003. "Halving Global Poverty." *Journal of Economic Perspectives*

17(3):2–22.

Browning, M., P.A. Chiappori, and Y. Weiss. 2007. *Family Economics*. Cambridge: Cambridge University Press.

Bryan, G., S. Chowdury, and A.M. q Mobarak. 2014. "Underinvestment in a Profitable Technology: The Case of Seasonal Migration in Bangladesh." *Econometrica* 82(5):1671–1748. Available at: http://doi.wiley.com/10.3982/ECTA10489.

Card, D. 2001. "Estimating the return to schooling: Progress on some persistent econometric problems." *Econometrica* 69(5):1127–1160.

Cook, T.D., and W. Shadish. 2012. "DESIGN AND ANALYSIS OF PRACTICAL QUASI-EXPERIMENTS FOR USE IN EDUCATION RESEARCH." *Institute for Policy Research (IPR) Northwestern University*. Available at: https://www.ipr.northwestern.edu/workshops/past-workshops/quasi-experimental-design-and-analysis-in-education/quasi-experiments/docs/QE-Day2.pdf.

Dollar, D., and A. Kraay. 2002. "Growth Is Good for the Poor." *Journal of Economic Growth* 7(3):195–225.

Donaldson, D. 2018. "Railroads of the Raj: Estimating the Impact of." *American Economic Review* 108(4–5):899–934.

Doss, C.R., and M.L. Morris. 2000. "How does gender affect the adoption of agricultural innovations?" *Agricultural Economics* 25(1):27–39.

Duflo, E. 2000. "Grandmothers and Graddaughters: Old Age Pension and Intra-Household Allocation in South Africa." *The World Bank Economic Review* 17(1):1–25.

Duflo, E. 2012. "Women Empowerment and Economic Development." *Journal of Economic Literature* 50(4):1051–1079.

Filmer, D. 2005. "Gender and wealth disparities in schooling: Evidence from 44 countries." *International Journal of Educational Research* 43(6):351–369.

Frey, C.B., and M.A. Osborne. 2017. "The future of employment: how susceptible are jobs to computerisation?" *Technological forecasting and social change* 114:254–280.

Ganle, J.K., K. Afriyie, and A.Y. Segbefia. 2015. "Microcredit: Empowerment and disempowerment of rural women in Ghana." *World Development* 66:335–345. Available at: http://dx.doi.org/10.1016/j.worlddev.2014.08.027.

Gates, M.F. 2014. "Putting women and girls at the center of development." *Science* 345(6202):1273–1275.

Ghosh, M. 2017. "Infrastructure and Development in Rural India." *Margin- The Journal of Applied Economic Research* 11(3):256–289.

Gibbs, A., S. Willan, A. Misselhorn, and J. Mangoma. 2012. "Combined structural interventions for gender equality and livelihood security: A critical review of the evidence from southern and eastern Africa and the implications for young people." *Journal of the International AIDS Society* 15(Suppl 1).

Government of India. "Area & Population." Available at: http://censusindia.gov.in/Census_And_You/area_and_population.aspx [Accessed April 3, 2019].

Government of India. 2012. "PRADHAN MANTRI GRAM SADAK YOJANA - Programme Guidelines."

Griliches, Z. 2006. "Estimating the Returns to Schooling: Some Econometric Problems." *Econometrica* 45(1):1.

Harper, C., K. Nowacka, H. Alder, and G. Ferrant. 2014. "Measuring women's empowerment and social transformation in the post-2015 agenda." Available at: https://www.odi.org/publications/8257-measuring-womens-empowerment-and-social-transformation-post-2015-agenda [Accessed April 1, 2019].

Hashemi, S., R.S. Schuler, and A.P. Riley. 1996. "Rural credit programs and women's empowerment in Bangladesh." *World Development* 24(4):635–653.

Husain, Z., D. Mukherjee, and M. Dutta. 2014. "Self Help Groups and empowerment of women: Self-selection or actual benefits." *Journal of International Development* 26(4):422–437.

Imbens, G., and T. Lemieux. 2007. "REGRESSION DISCONTINUITY DESIGNS: A GUIDE TO PRACTICE."

Jacob, R.T., P. Zhu, M.-A. Somers, and H. Bloom. 2012. "A Practical Guide to Regression Discontinuity." *MDRC Building Knowledge to Improve Soical Policy* (July):1–100. Available at: http://www.mdrc.org/practical-guide-regression-discontinuity.

Lehne, J., J.N. Shapiro, and O. V Eynde. 2018. "Building connections: Political corruption and road construction in India." *Journal of Development Economics* 131(2018):62–78. Available at: http://dx.doi.org/10.1016/j.jdeveco.2017.10.009.

Lemieux, T. 2011. "Lecture 1 : Introduction to Regression Discontinuity Designs in Economics Plan of the three lectures on regression discontinuity designs." *University of Coimbra*.

Mahmud, M., and Y. Sawada. 2018. "Infrastructure and well-being: employment effects of Jamuna bridge in Bangladesh." *Journal of Development Effectiveness* 10(3):327–340. Available at: https://www.tandfonline.com/doi/full/10.1080/19439342.2018.1483415.

McCrary, J. 2008. "Manipulation of the running variable in the regression discontinuity design: A density test." *Journal of Econometrics* 142(2):698–714. Available at: http://www.sciencedirect.com/science/article/pii/S0304407607001133%5Cnhttp://www.sciencedirect.com/science?_ob=MiamiImageURL&_cid=271689&_user=486651&_pii=S0304407607001133&_check=y&_origin=article&_zone=toolbar&_coverDate=29-Feb-2008&view=c&originContent.

Mellor, J.W. 2017. *Agricultural Development and Economic Transformation: Promoting Growth with Poverty Reduction*.

ModU. 2015. “Your guide to regression discontinuity module.” *Social Science Research Institute Duke University*. Available at: https://modu.ssri.duke.edu/module/your-guide-regression-discontinuity [Accessed April 29, 2019].

Monitoring and Accounting System (OMMAS). “PRADHAN MANTRI GRAM SADAK YOJANA.” Available at: http://omms.nic.in/ [Accessed April 3, 2019].

Montenegro, M. 2016. *Land Rights and Women ’ s Empowerment in Rural Peru : Insights from Item Response Theory*. University of Alberta.

Morten, M., J. Oliveira, T. Allen, M. Alsan, A. Barufi, G. Bryan, K. Casey, A. Chandrasekhar, R. Dix-Carneiro, D. Donaldson, T. Dinkelman, P. Dupas, F. Finan, D. Fitzger-Ald, P. Gertler, D. Gollin, S. Jha, B. Kovak, K. Mangum, A. Minian, M. Mobarak, D. Mckenzie, P. Pereda, N. Qian, S. Redding, M. Rosenzweig, and S. Schulhofer-Wohl. 2018. “The Effects of Roads on Trade and Migration: Evidence from a Planned Capital City.” Available at: https://web.stanford.edu/~memorten/ewExternalFiles/Morten_Oliveira_Brasilia.pdf.

Moser, C.O. 2012. *Gender planning and development: Theory, practice and training*. Routledge.

OECD. 2014. “Gender Equality: Balancing paid work, unpaid work and leisure.” Available at: http://www.oecd.org/gender/data/balancingpaidworkunpaidworkandleisure.htm [Accessed April 1, 2019].

Ozier, O. 2011. “The Impact of Secondary Schooling in Kenya : A Regression Discontinuity Analysis.” *Policy Research Working Paper* 30(January):1869–1878. Available at: http://economics.ozier.com/owen/papers/ozier_JMP_20110117.pdf.

Pattison, J.K. 2017. *Margins in the Mountains: Poverty Dynamics in India’s Western and Eastern Ghats*.

Paul Schultz, T. 2002. “Why governments should invest more to educate girls.” *World Development* 30(2):207–225.

Rahman, L., and V. Rao. 2004. “The Determinants of Gender Equity in India: Examining Dyson and Moore’s Thesis with New Data.” *Population and Development Review* 30(2):239–268.

Ravallion, M. 2001. “Growth Inequality and Poverty: Looking beyond Averages.” *World Development* 29(11):1803–1815.

Reserve Bank of Inida. 2013. “Number and Percentage of Population Below Poverty Line.” Available at: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=15283.

Salia, S., J. Hussain, I. Tingbani, and O. Kolade. 2018. “Is women empowerment a zero sum game? Unintended consequences of microfinance for women’s empowerment in Ghana.” *International Journal of Entrepreneurial Behavior & Research* 24(1):273–289.

Shamdasani, Y. 2018. “Rural Road Infrastructure and Agricultural Production: Evidence from India.”

Sharma, S. 2016. “Achieving Gender Equality in India: What Works, and What Doesn’t.” *United Nations University*. Available at: https://unu.edu/publications/articles/achieving-gender-equality-in-india-what-works-and-what-doesnt.html.

Singh, I., L. Squire, and J. Strauss. 1986. “Agricultural Household Models: Extensions, Applications, and Policy.”

Skoufias, E. 1993. “Labor market opportunities and intrafamily time allocation in rural households in South Asia.” *Journal of Development Economics* 40(2):277–310.

Smith, L.C., and L. Haddad. 2015. “Reducing Child Undernutrition: Past Drivers and Priorities for the Post-MDG Era.” *World Development* 68(1):180–204. Available at: http://dx.doi.org/10.1016/j.worlddev.2014.11.014.

Sveiby, K.-E., P. Gripenberg, B. Segercrantz, A. Eriksson, and A. Aminoff. 2009. “The Unintended and Undesirable Consequences of Innovation.” In *XX ISPIM conference The Future of Innovation Vienna*.

Tomich, T. P., Kilby, P., Johnston, B. F., & Izumida, Y. 1997. “Transforming agrarian economies: Opportunities seized, opportunities missed.” *Developing Economies* 35(3):338–330.

UN Women. 2018. “Facts and Figures: Economic Empowerment.” Available at: http://www.unwomen.org/en/what-we-do/economic-empowerment/facts-and-figures [Accessed April 1, 2019].

United Nations. “Goal 5: Achieve gender equality and empower all women and girls.” Available at: https://www.un.org/sustainabledevelopment/gender-equality/ [Accessed April 1, 2019].

United Nations Development Programme (UNDP). 1994. *Human Development Report 1994*.

United Nations Development Programme (UNDP). 2019. “Human Development Reports: Gender Inequality Index (GII).” Available at: http://hdr.undp.org/en/content/gender-inequality-index-gii [Accessed April 1, 2019].

Unterhalter, E., A. North, M. Arnot, C. Lloyd, L. Moletsane, E. Murphy-Graham, J. Parkes, and M. Saito. 2014. “Girls’ education and gender equality.” Available at: http://r4d.dfid.gov.uk/.

Veettil, P.C., B.K. Mohapatra, P.T. Raghu, and S. Mohanty. 2016. “Youth in Agriculture : Involvement and Career Preferences of Rural Youth across Rice Value Chain.”

World Bank. 2011. “Gender Equality and Development.” Available at: https://siteresources.worldbank.org/INTWDR2012/Resources/7778105-1299699968583/7786210-1315936222006/Complete-Report.pdf.

World Bank. 2006. “Gender equality as smart economics: A World Bank Group Gender Action

Plan (Fiscal years 2007–10)."

World Bank. 2018. "India States Briefs." Available at: http://www.worldbank.org/en/news/feature/2016/05/26/india-states-briefs.

World Bank. 2017. "Popuation Totals." Available at: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=IN-CN.

World Economic Forum. 2018. *The Global Gender Gap Report*. Available at: https://www.weforum.org/reports/the-global-gender-gap-report-2018 .

Yamano, T. 2015. "Rice Monitoring Survey: South Asia." Available at: http://ricestat.irri.org/fhsd/php/panel.php.

Yamano, T., P. Veetil, I. Gupta, J. Johny, D. Villanueva, P. Ricarte, and H. Valera. 2017. "Rice Monitoring Survey 2016 in India."

Zepeda, L., and M. Castillo. 2006. "The Role of Husbands and Wives in Farm Technology Choice." *American Journal of Agricultural Economics* 79(2):583.

## Paper 2: Intra-household Pareto Inefficiency along the Marginal Distribution of Yields: A Study of Women's Agricultural Productivity in India

## 1. Introduction

Increases in the productivity of women engaged in agriculture are believed to yield high returns in the form of greater empowerment for women, increased welfare for their households, and increased productivity of the agricultural sector in an economy (Schultz 2001). Consequently, in recent years, there has been a strong emphasis on targeting resources towards women farmers in developing countries (e.g., World Bank 2007; Harper et al. 2014; Gates 2014; United Nations 2005). Scholars, however argue that the empirical basis for explicitly targeting women with the goal of increasing their productivity still remains weak, and more research is needed for informing such development policies (Doss et al. 2015; Doss 2018).

A large and growing body of literature has sought to explain if women farmers are inherently less productive then men farmers; or if the gender-differentiated profitability rates can be explained by differences in the constraints faced by women relative to men. Studies have addressed this issue, most commonly with cross-sectional and plot-level panel regressions of yields using the gender of the plot owner as a covariate. Much of this literature has found no significant difference in men's and women's agricultural productivity after controlling for plot, farmer, household and market characteristics. This finding implies that women would be as productive as men if they had the same access to resources and opportunities as men (e.g., Parveen 2008; Kelkar 2009; Adeleke et al. 2008; Saito, Mekonnen and Spurling 1994; Vargas Hill and Vigneri 2011; Moock 1976).

Understanding women's productivity with respect to agricultural production, however, requires a shift away from the unitary common preference model for a number of reasons. First, male and female household members have been shown to have distinct preferences over consumption, have different levels of decision-making power, and are often independently responsible for farming plots owned by or assigned to them. Decision-making in these households is, therefore, more appropriately represented by an intrahousehold model. One of the most widely used models is the collective household model, which maintains that male and female household members with different preferences maximize household utility and achieve Pareto efficient outcomes through cooperation and bargaining (Browning and Chiappori 1998; Chiappori and Weiss 2007; Manser and Brown 1980). These models assume that male and female household leaders bargain over the allocation of resources until no one can be made better off without negatively impacting others; more specifically, the marginal returns to inputs are equal across production activities run by different household members. Second, households are often both producers and consumers. Thus, accurately depicting the economic behaviour of households that consume a significant proportion of their own output relies on the theory of agricultural household decision-making; which emphasizes the complex interwoven relationships between labour allocation, consumption, and production decisions (Singh, Squire and Strauss 1986). This relationship becomes increasingly more complex with labour and financial market failures; because under these conditions household utility maximization is no longer separable from production (de Janvry, Fafchamps and Sadoulet 1991). In the presence of non-separability, consumption side variables such as the number of children in the household (that are not used as labour inputs in household production) affect production decisions.

The implication of intra-household decision making on women's productivity in agriculture was modelled in a seminal contribution by Udry (1996), which has spawned a considerable literature on this issue. The Udry study shows that in agricultural households in Burkina Faso, plots of land managed by women are less productive compared to those farmed by men (viz., their husbands). The discrepancy in productivity is attributed to differences in the intensity of the application of labour and fertilizer across male and female-owned plots within the household. Thus, according to this literature (see e.g., Owens 2001), a reallocation of land from wives to their husbands, keeping the allocation of labour and other inputs constant, could significantly increase total agricultural production.[10]

These findings, however, leave many open questions. First, strikingly, they imply that the allocation of household resources is not Pareto efficient. Thus, even under extreme scarcity, household decision-makers fail to be efficient in their production choices. Hence, while the unitary household model is clearly inadequate for studying intra-household decisions, the literature following Udry (1996) finds that the collective household model is also inadequate for modelling household production. Second, a study by Rangel and Thomas (2012) using both consumption and production data on households in Ghana and Senegal, finds that the allocation of household resources towards consumption is Pareto efficient, while the allocation of resources towards production activities are not, for the *same* households. Finally, adding to the mixed results, studies based on the consumption choices of households in more developed areas such as Canada, U.S.A, Mexico and Taiwan have repeatedly found that that household resources are allocated Pareto efficiently (e.g., Browning and Chiappori 1998; Bourguignon et al. 1993; Bobonis 2009; Thomas and Chen 1994; Chiappori, Fortin and Lacroix 2002).

Recently, scholars have argued that discarding the collective household framework for modelling smallholder decisions in poor economies is not justified given the current empirical evidence (e.g., Akresh 2008; Rangel and Thomas 2012). These studies attribute findings of

[10] These findings relate to the effect of input re-allocation between women and men, rather than the effect of giving women the same access and inputs as men, as suggested in the other literature discussed earlier. This result implies that, holding constant the economic environment of access and ownership of resources, agricultural production in a household and, thereby, in the economy can be increased by transferring inputs from men to women within families.

Pareto inefficiency to small samples, weak statistical tests, lack of proper data, and unobserved heterogeneity. Thus, Pareto inefficiency in resource allocation of smallholder farms in poor countries still remains an open empirical question. Unfortunately, the development literature offers no clear answers and there is still a sense among those working in the field that more needs to be done to address the central policy question regarding women's agricultural productivity (Doss 2018).

In this paper, we revisit the issue of women's agricultural productivity using a large and detailed plot-level dataset collected from residents of rural India. Our approach is primarily empirical and we use a reduced form model that draws on the collective household model and the previous literature on detecting Pareto inefficiency in the allocation of household production resources. We depart from the previous literature in that we treat household resource allocations to lie in the continuum between Pareto efficient and inefficient based on *observed household attributes* (social norms, exposure to shocks, market access) and *unobserved factors* (such as varying levels of integration into markets) that vary along the marginal distribution of yields.

Our use of observed covariates to detect heterogeneity in Pareto efficiency is similar to the recent work by Akresh (2005), who shows that in periods of negative rainfall shocks, households change their allocations to overcome losses due to Pareto inefficiency. Our use of a distributional approach to characterize heterogeneous levels of Pareto inefficiency has not been explored in previous studies. Given the difficulty of overcoming the confounding influences of unobserved heterogeneity in models of household production efficiency, this is a significant contribution. Further, we examine if consumption side factors play a role in determining production efficiency. If they do, then ignoring their role could bias previous estimates of Pareto inefficiency. While non-separabilities are common in poor agrarian economies, their role has been ignored in all previous studies on intra-household production efficiency.

We have three objectives: first, we estimate whether or not households in rural India attain Pareto efficiency in allocating resources across production activities undertaken by male and female household members. To do so, we follow the procedure set forth by Udry (1996) (also see Rangel and Thomas 2012) and estimate yield regressions that allows us to test for Pareto efficiency by examining the coefficient on a variable denoting the gender (husband or wife) of the household member who owns the plot, while controlling for all other household influences.[11]To the best of our knowledge, this is the first application of the empirical intra-household production model outside of West Africa. Thus, this study allows us to examine if, as pondered by many scholars, Pareto inefficiency in production is a phenomenon specific to the characteristics of West African households (e.g., see Rangel and Thomas 2012; Owens 2001).

Our second objective is to explore if household Pareto efficiency varies over observed and unobserved factors across the distribution of yields. For instance, social norms, such as those based on the caste system in India, can force a production equilibrium for a household that is seemingly inefficient by deliberately allocating resources away from women's plots. Further, the effect of such factors may change given a household's position in the yield distribution. Highly able and productive farms at the top of the yield distribution may overcome some of their cultural constraints to avoid losses associated with the inefficiencies they create (e.g. higher caste individuals face less cultural constraints). In addition, heterogeneity in Pareto efficiency can arise

[11] On the methods used to research this objective; as pointed out by Doss (2017) issues of identification may be present given the nature systematic differences in plots owned by males and females. One way to overcome these issues is to use information on how land was acquired, such information will be used in future work to better identify the inefficiency present between male and female owned plots.

due to the fact that plots at high and low ends of the unconditional yield distribution are structurally different for unobserved reasons. For example, less productive farms often face land constraints resulting in low marginal productivity on-farm which triggers out migration of younger educated members, therefore, a negative effect on technology adoption and use of modern methods are often observed (HLPE 2016). Less productive farms may also be less well integrated into financial and commodity markets making them more likely to be inefficient.

Our third objective is to evaluate if the non-separable preference and consumption side variables play a role in determining the Pareto efficient allocation of household production resources. We test for the presence of non-separability and account for it by examining if consumption side variables, such as the number of children in the household, affect production. The significance of this variable is an indication that any Pareto inefficiency is in fact related to the conscious choice of household members who trade-off farm productivity for better quality children.

In order to meet the objectives outlined in this study, we use detailed data on household agricultural production with plot and household-level information. The dataset provides insights on gender and its effects on production – a rare characteristic of the data. We estimate yield regressions using a large cross-sectional survey administered by the International Rice Research Institute (IRRI) in 2016 that provides information on household members, specifically focusing on the main male and female decision-maker. Moreover, our data also contains information on who is in charge of production and many other plot-level characteristics. The data covers over 10,000 plots for 8000 households. Further, the data includes a detailed description of household composition, such as the number of children, shocks and agricultural education extension services available to the household which provides a unique opportunity to understand Pareto efficiency and the role of consumption side variables (e.g. household head education, castes, etc.) in amplifying or mitigating the (in)efficiency.

This study makes three novel contributions. Firstly, this study contributes to the household modelling and decision making literature; specifically, we add to the literature pertaining to Pareto efficiency and resource allocation. This study aims to provide insights on Pareto efficiency in India, a country where both agriculture and the role of women are central issues. Secondly, we build on the concepts of Pareto efficiency by examining it along the distribution of yields. This allows us to show how observed and unobserved factors work together to create such inefficiencies. Lastly, we contribute to the literature in a novel way by testing the validity of the separability assumption used in many collective household models. This study also adds to the growing literature that supports investments that target women in agriculture, by showing that efficient investments in women have the potential to increase much more than just production. Rather, such investments have the potential to increase production/ income (reduce poverty), as well as empower women.

The remainder of the paper is organized as follows. Section 2 provides the background of the literature available and relevant to the study. Section 3 describes the context, as well as the data used. Section 4 outlines the estimation procedures used in the study. Section 5 explains the empirical specification, while section 6 outlines the estimation procedures used in the study. The results of the models also outlined in section 7. Lastly, section 8 is the conclusion of the study.

## 2. Background

It is increasingly being recognized in policy circles that investing in the productivity of women in agricultural productions holds high returns. According to estimates of the FAO (SOFA and Doss 2011), women make up a substantial proportion of the agricultural workforce and are responsible for the production of most food crops in developing countries (Gupta 2009; Bain 2011). Women also play a central role in the determination of household food security and welfare in developing countries (Bunch and Mehra 2008).

Yet, women remain an under-used economic resource in many developing countries: they participate less in formal labour markets, earn lower wages, own fewer resources and play a smaller role in major household economic decisions (World Bank 2011). Women's access to, and control over key agricultural resources, such as land and credit, are often weaker than men's (Duncan and Brants 2004). The low status of women is exacerbated by agricultural development projects which often fail to recognize gender based patterns – the roles and functions performed by both men and women – and instead assumed male dominance in agricultural communities (World Bank, FAO and IFAD 2009;Carr 2008; Hurni and Osman-Elasha 2009; Sachs 1996).

The renewed policy focus is also motivated by increasing recognition of critical linkages between agriculture and women. Due to the fact that women are heavily involved in agriculture and frequently left out of development efforts, there is a high potential for returns to investing in this untapped resource. Women are half of the potential human capital of most economies, as a result, simply optimizing women's potential can substantially raise household productivity and overall aggregate agricultural production (Mohapatra and Luckert 2014). For instance, it is estimated that if women and men had the same access to productive resources, farm yields would increase by 20–30 percent (SOFA 2011; Doss 2018). Moreover, women hold an instrumental role in the household, which pertains to child health, nutrition and education; thus, by improving the well-being and opportunities of women it is possible to have positive effects on the next generation (i.e. social externalities) (Doss and Morris 2000). Therefore, the interconnected nature often observed in developing countries between women and farmers provide a precedent for direct development towards this group.

While women play a significant role in the agricultural sector, the agricultural sector is considered a tool for poverty alleviation  (Ravallion and Chen 2003; Kraay 2006). The Sustainable Development Goals (SDGs) set forth by the United Nations (UN) have fostered a focus on development that encourages poverty reduction through the ability of the poor to participate in growth (Christiaensen, Demery and Kuhl 2011). Investments in agriculture contribute to poverty reduction at a higher rate than comparable investments made in any other sector of an economy (World Bank et al. 2009). In fact, in many countries, agriculture has been shown to be 3.2 times more effective at reducing extreme poverty than other sectors of the economy (Christiaensen et al. 2011). Due to the pro-poor nature of agriculture centred policies, scholars consistently advocate for policies and investments that support the development of agriculture (World Bank 2007; Ellis 2005; Dercon 2009; Buehren et al. 2017). Modern growth, driven largely by skill intensive sectors often leaves the poor and the most vulnerable subpopulations behind.

## 3. Context and Data

The plot, individual, and household-level socioeconomic data used in this study was collected by IRRI as part of the annual Rice Monitoring Survey (RMS). The survey focused on the eastern region of India, specifically the four states of Bihar, Odisha, West Bengal, and Eastern Uttar Pradesh (Figure 2-1). This region is frequently studied because it is classified as one of the least developed areas in India, and consistently lags behind the rest of the India in many development indicators, as displayed in Table 2-1 (Reserve Bank of India 2013; World

Bank 2018). While many states have made progress in areas like education and health, India as a whole continues to exhibit a number of social and structural barriers that have many adverse effects, including large gender gaps in several aspects of social and economic life (World Economic Forum 2018).

The RMS project scheme (implemented through the support of the Bill and Melinda Gates Foundation) includes an annual survey of agriculture dependent (rural) households that collects information on socioeconomic status, farm practices, and grown seeds, among other (Yamano 2015). For this specific study we focus on the 2016 version of the RMS survey, which collected information on a number of factors pertaining to rural households, specifically this survey aimed to examine shifts in household production practices (e.g. varietal turnover and climate change adoption), as well as gender-disaggregated data on household activities and decision making (Yamano et al. 2017). In order to meet the objectives outlined in this study, we primarily relied on the gender-disaggregated data, as it allows us to examine differences between males and females.

The villages considered in this study were those involved in the 2016 RMS survey, where villages and households were selected as follows: (1) rural villages were randomly selected from the 2011 Census of India, where the total number of sample villages selected in each state was proportional to the total number of rural villages in the state; (2) all households in the selected villages completed an initial census conducted by IRRI; (3) from the households included in the initial census that had male and female decision-makers, approximately twelve were selected randomly from each village for participation in the 2016 RMS survey. Due to the sensitive nature of the survey, gender-sensitive enumeration methods were employed in order to minimize the gender influence and gather the most truthful response. Male enumerators surveyed male respondents and female enumerators surveyed female respondents (Yamano et al. 2017).

Samples selected across the states are reported in Table 2-2. Village, household, and individual breakdowns remained relatively consistent and equally distributed. The highest numbers were selected from Odisha, followed by Bihar, West Bengal and Eastern Uttar Pradesh respectively. The total dataset included 720 villages, 8,639 households, and 38,756 individuals across four states in the eastern region of India (Table 2).

The RMS data provide information on household production and productive outputs. For this study, our sample is made of 10,941 plots, with 8,691 owned by men and 320 owned by women (Table 2-3).[12] Plot and household-level characteristics described in Table 2-3 play an important role in identifying inefficiencies and unequal production. On average it can be observed that women-owned plots have lower yields than men-owned plots. That being said women-owned plots also receive lower amounts of labour and inputs (Table 2-3). Furthermore, our study focuses on the Kharif growing season in India, a season primarily dominated by rice production. Table 2-4 provides a breakdown of the crops grown on plots owned by women and men. Overall, the distribution of crop types is relatively equal and proportional across genders.

---

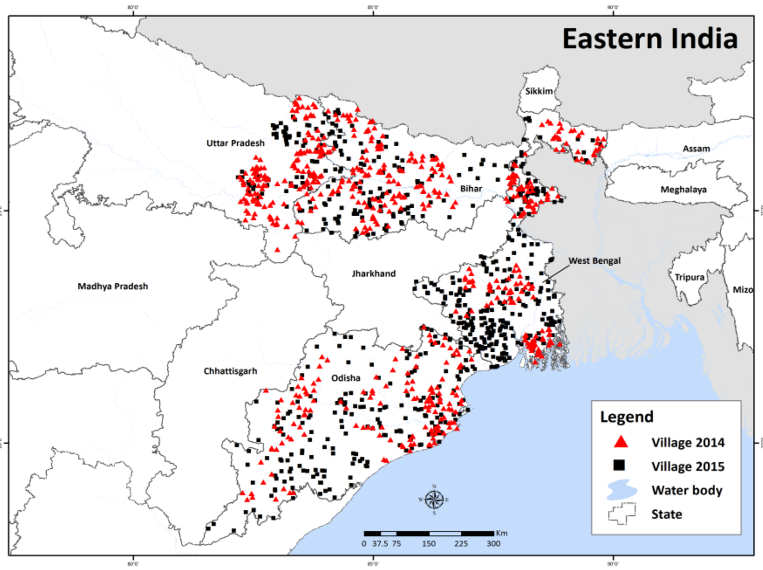
[12] In our data set, the remaining plots not owned by the male or female were "owned by non-household members"

**Table 2-1**: State wise development indicators for all states in India summarized from the World Banks "India State Briefs" for 2013

| | **Total Population (millions)** | **Poverty Rate (%)** | **Literate (% adults)** | **Electrification (%households)** | **Drinking Water on Premises (%households)** | **Open Defecation (%households)** | **Road Density (km / million people)** |
|---|---|---|---|---|---|---|---|
| **Assam** | 31 | 32 | 82 | 61 | 81 | 12 | 8,990 |
| **Bihar** | **104** | **34** | **58** | **31** | **73** | **68** | **1,306** |
| **Chhattisgarh** | 26 | 40 | 71 | 87 | 27 | 68 | 2,915 |
| **Gujarat** | 60 | 17 | 73 | 95 | 70 | 35 | 2,266 |
| **Haryana** | 25 | 11 | 75 | 96 | 77 | 17 | 1,657 |
| **Himachal Pradesh** | 7 | 8 | 79 | 97 | 61 | 22 | 7,275 |
| **Jharkhand** | 33 | 37 | 62 | 69 | 29 | 74 | 783 |
| **Karnataka** | 61 | 21 | 73 | 97 | 55 | 45 | 4,902 |
| **Kerala** | 33 | 8 | 94 | 96 | 76 | 2 | 6,423 |
| **Madhya Pradesh** | 73 | 32 | 67 | 87 | 34 | 61 | 2,729 |
| **Maharashtra** | 112 | 17 | 80 | 94 | 64 | 34 | 3,487 |
| **Odisha** | **42** | **33** | **68** | **70** | **27** | **73** | **6,002** |
| **Punjab** | 38 | 8 | 75 | 98 | 87 | 16 | 3,347 |
| **Rajasthan** | 69 | 15 | 59 | 82 | 51 | 58 | 3,569 |
| **Tamil Nadu** | 72 | 12 | 78 | 98 | 47 | 42 | 3,152 |
| **Uttar Pradesh** | **200** | **29** | **60** | **51** | **63** | **61** | **1,987** |
| **Uttarakhand** | 10 | 11 | 77 | 95 | 61 | 16 | 5,143 |
| **West Bengal** | **91** | **20** | **72** | **78** | **36** | **30** | **3,418** |
| **India** | **1211** | **22** | **70** | **80** | **56** | **44** | **3,231** |

Note: This table presents the indicators calculated my the World Bank in their "India State Briefs" (World Bank 2018)

**Figure 2-1**: Map of Eastern India depicted IRRI Rice Monitoring Villages in 2014 and 2015




Note: This map is a depiction of the International Rice Research Institutes Rice Monitoring Survey study area. The area is comprised of four states in the eastern region of India: Bihar, Odisha, Eastern Uttar Pradesh and West Bengal. The village 2014 villages provide an approximation of the villages used in the 2016 as same villages were targeted.

**Table 2-2**: Village, household and individual level composition by state, Eastern India, 2016

| | **Village composition (%)** | **Household composition (%)** | **Individual Composition (%)** |
|---|---|---|---|
| **Bihar** | 176 (24.4%) | 2,112 (24.4%) | 10,325 (26.6%) |
| **Odisha** | 225 (31.3%) | 2,699 (31.3%) | 11,203 (28.9%) |
| **Uttar Pradesh (Eastern)** | 151 (21.0%) | 1,812 (21.0%) | 9,639 (24.9%) |
| **West Bengal** | 168 (23.3%) | 2,016 (23.3%) | 7,589 (19.6%) |
| **Total** | 720 (100%) | 8,639 (100%) | 38,756 (100%) |

Note: This table presents the breakdown of observations by state.

**Table 2-3**: Mean yields, area and labour inputs by gender of plot owner, Eastern India, 2016

| | **Plot Ownership (Count)** | **Harvested Yield (kg/ acre)** | **Area (acre)** | **Male Labour (hours per crop)** | **Female labour (hours per crop)** | **Hired Male Labour (hours per crop)** | **Hired Female Labour (hours per crop)** | **Inputs (kg)** |
|---|---|---|---|---|---|---|---|---|
| Male | 8,691 | 1082.052 | 4.958714 | 24.17534 | 7.523846 | 144.9406 | 82.40429 | 302.4869 |
| Female | 320 | 1004.445 | 4.630332 | 23.65938 | 9.915625 | 84.33125 | 77.73125 | 311.8012 |

Note: This table was derived using the plots that fell between the 5% and 95% of the yield distribution – plots below (150 kg/ acre) and above (2250 kg / acre) these points were dropped in order to obtain a more accurate result.

**Table 2-4:** Distribution of primary crops across plots by gender, Eastern India, 2016

| | **Male** | **Female** |
|---|---|---|
| Rice (traditional) | 2,427 (31%) | 91 (28%) |
| Rice (HYV) | 3,692 (47%) | 175 (55%) |
| Rice (Hybrid) | 1,517 (19%) | 50 (16%) |
| Maize (traditional) | 301 (3%) | 4 (1%) |

Note: This table was derived using the plots that fell between the 5% and 95% of the yield distribution – plots below (150 kg/ acre) and above (2250 kg / acre) these points were dropped in order to obtain a more accurate result.

## 4. Conceptual model

According to the collective household model (Browning and Chiappori 1998; Browning, Chiappori and Weiss 2007), male and female household members with different preferences maximize a weighted sum of their individual utility functions. The weight denotes the power over household decisions, and is believed to depend on factors such as exogenous income received by a person, and age and education differences between the individuals. Within the household, individuals bargain to reach an outcome (e.g. decision), and individuals with a higher level of decision-making power will display a greater influence on the final household outcome. Regardless of bargaining and differential preferences, the collective model assumes that household allocation of resources is Pareto efficient.

The results generated through the collective model of households have strong policy implications for influencing household consumption behaviour. Policies such as micro-credit programs are occasionally designed to explicitly target women because women are believed to make economic choices that improve household welfare and contribute to economic development. For instance, money given to women rather than men is believed to accelerate economic development because women's expenditures favour the accumulation of children's human capital. The assumption underlying this effect is that women have stronger more household-centric preferences than men, and those preferences can be mobilized by improving their bargaining power (Duflo 2000).

The bulk of collective household models focus on households' consumption behaviour. However, differences in the preferences, bargaining, and cooperation between men and women, have implications for farm productivity, which may or may not lead to productive Pareto (in) efficiency (e.g. yield and input differences). Studies by Apps and Rees (1996) and Chiappori (1997) extend the collective utility maximization framework to include production decisions. Additionally, Udry (1996) uses data on household agricultural production that is carried out on many plots, which are controlled by different members, to empirically test if the allocation of resources across plots is efficient. Such studies also represent the theoretical basis of women's agricultural productivity frequently explored in the literature. Thus, a description of the framework used in the previously mentioned studied is explained as follows.

Household utility is defined over leisure, private goods (e.g., clothing) and a public good (e.g., children education). Household members display a common preference only over the public good, which is produced using the non-leisure time of household members. Additionally, household members supply labour to the production of agricultural commodities on multiple plots of land, which are managed by individual household members. Under this setup, the household solves its production problem (public good and agricultural production), its labour supply allocation (public and agricultural labour) and its utility maximization (for leisure, private goods and the public good) using a pooled budget that includes profits from agricultural production.

Production and consumption are assumed to be separable and recursive such that the optimization can be thought of as a two-stage problem. The household will first choose labour inputs to produce agricultural output, and then choose consumption bundles conditional on labour amounts and the full income which includes profits from the first stage. A consequence of separability is that consumption side variables, such as the number of children and their quality, do not directly affect production decisions (except for indirect labour supply or other time constraint channels). Issues arise as separability may not hold in the presence of market failures, which are common in poor economies. Even when market imperfections are present, studies that use intra-household production models assume away separability. Such assumptions include as additively separable preferences or constant returns to scale production technologies which maintain the separability of the consumption and production sides, even if market failures are present (Couprie 2007).

Pareto efficiency in production under this circumstance implies that it should not be possible to reallocate inputs within households and achieve a higher level of aggregate output. This notion is the foundation of our empirical work, and is described in next section. However, we build on the models used to examine Pareto efficiency in Udry's framework. Unlike the framework by Udry (1996), we do not consider inefficiency as an absolute concept and include heterogeneity in the level of efficiency across households.

In this study, we allow for observed heterogeneity in Pareto efficiency by examining how social factors such as caste, availability of credit, and extension services mitigate Pareto efficiency. These factors represent different costs and barriers that could limit certain households from achieving a higher equilibrium even when it is feasible. We allow for unobserved differences in Pareto efficiency by examining the optimal allocation of household resources across the yield distribution. Pareto efficiency may differ across the yield distribution both due to direct changes in barriers to efficiency and due to differences in the role of the mediating factors, discussed above, across the yield distribution.

## 5. Empirical strategy

We follow Udry's (1996) identification strategy to specify our baseline model. Given the assumption of separability between consumption and production decisions, production efficiency implies that marginal returns to inputs, are the same across plots and do not depend upon who manages the plot. On two plots, with equal areas of land, production is equal. Therefore, if households allocate their productive resources efficiently, then differences in yields are *only* due to differences in plot characteristics:

$$Q_{hci} = X'_{hci}\beta + \gamma G_{hci} + \lambda_h + \lambda_c + Z'\delta + \varepsilon_{hci} \qquad (1)$$

where $Q_{hci}$ is the logged yield on plot *i* planted with crop *c* during a single season by a member of household *h;* $X'_{hci}$ is a (1 x k) matrix of plot characteristics such as plot area, land type, and location with corresponding coefficient (k x 1) vector $\beta$; $G_{hci}$ denotes a dummy denoting the gender of the individual that owns the plot (female=1); $\lambda_h$ and $\lambda_c$ denote household and crop specific differences in yields; $Z'$ denotes a set of additional covariates; and $\varepsilon_{hci}$ is assumed to be an i.i.d (independent, identically distributed) error term.

Evaluating yield differences between men and women is complicated, even with data on plots assigned by gender, due to potential differences in yields across crops, or across households characterized by heterogeneous entrepreneurial ability and idiosyncratic shocks (Doss 2017). The inclusion of the unobserved household and crop effects restricts attention to variation in yields across plots planted to the same crop, within households, in the same season (Udry 1998). Under this setup, a test of Pareto efficiency (the overall inefficiency experienced), or the equality of marginal products across male and female managed plots, is a test of statistical significance of the $\gamma$ in equation 1 (objective 1).

To account for constraints and costs that may prevent subgroups of households in achieving Pareto efficiency (objective 2), we extend equation 1 by including additional explanatory variables Z. We include as control variables an indicator of the household's caste (the primary form of social stratification in India), women's access to extension services and credit, and an indicator of whether the plot experienced a shock (drought) during the previous growing season. Z also includes the interactions of these variables with the gender variable to determine the extent to which constraints and costs posed by these variables affect Pareto efficiency. Finally, to examine the implications of non-separability in production and consumption decisions we include a consumption side variable – the number of children aged 5 to 9 present in the household- and its interaction with the gender variable in the reduced form yield regression (equation 1). Children aged 5 to 9 were used to represent the consumption side because households must consciously decide to invest in children (i.e. for better quality children) instead of farm productivity. Moreover, this is due to the fact that children at this age require high levels of time and monitoring. It is possible that children aged 5 to 9 (kids) are actually not a consumption side variable, rather, it captures the effect of family labour on production. We account for this in two ways: (1) we chose only kids because they are less likely to be supplying labour; and (2) if kids present a labour supply effect the coefficient will be positive. Thus, to establish non-separability, a non-positive significant coefficient is expected for the interaction between women's ownership and the presence of children. Under non-separability we would expect this consumption side variable to have a significant effect on yields (however, a significant positive effect would not allow us to distinguish between non-separable consumption effects and the positive effect of child labour on yields).

Finally, it is possible that the barriers to Pareto efficiency may vary both within the variables in Z and along the distribution of yields (objective 3). For instance, social norms associated with a caste may be more flexible when yields are low- at the $25^{th}$ quantile of the yield distribution – compared to the top. Additionally, some studies have also argued that during times of shocks household members are likely to pull together and become more efficient than in times of less distress (Akresh 2018). Similarly, access to extension services and credit may create variances in yield, and also moderate household efficiency differently along the yield distribution.

Table 2-5 reports the predicted signs, descriptive statistics and definitions for all variables used in our analysis. To understand the rationales behind the signs, we outline our hypothesis by variable. Our dependent variable, as mentioned earlier, is the harvested yields (*Log Yield)*. The main covariate, gender, which allows us to test for Pareto efficiency is specified using a dummy variable for female (*Women ownership*). Approximately 4% of the plots in our data are owned by women. While this is a relatively low subset of the population, it is representative of the true proportion of land ownership observed in India. To address the possible problems with standard errors, and our reduced ability to find a significant gender effect when it exists due to the small number of women owners, we also present our main equations using bootstrapped standard errors.

Our plot characteristics, *X* in equation 1 includes *plot size,* which is expected to have a negative sign based on the commonly observed inverse farm-size productivity relationship in developing countries. Negative plot size relationships are often observed because of the lack of capacity to produce at scale (Barrett, Bellemare and Hou 2010). Due to our focus on the kharif growing season; we add variables that may reflect traits important to rice production. Firstly, we add a crop identifier that shows the yield effect of different crops. Since we are looking at kharif production, we hypothesize that plots planted with varieties of rice (*crop 1, crop 2, crop 3)* will have higher yields (kg/acre) than plots planted with other crops (*crop 4)*. Secondly, we include topography variables, as different topographies are better suited for different crops (*topography 1, topography 2, topography 3)*. Rice is better suited for growth in lowland topography (*topography 1),* therefore we hypothesize that plots situated on the lowlands will have higher yields than those in other topographic regions. Lastly, *state* dummies were included to capture the differences in climates and growing conditions that are present across states (*state1, state 2, state 3, state 4)*. Of the states included in our study, West Bengal is known to have the highest yields.

We include in Z, an indicator for high caste individuals (*caste*). Individuals belonging to high caste face fewer and different barriers socially and economically compared to lower caste. We also include a measure of exposure to drought (*shock*), a women's access to extension services (*extension)* and credit *(credit*) would positively impact women's production because of an increase in their ability to access services and inputs. Therefore, when looking at the impacts of these variables on women's inefficiencies in yield in this study – we would assume a positive effect. Lastly the education of the household head and the size of the household are believed to positively impact yields for both women and men – thus decreasing the inefficiencies observed in the household (*education)*. Finally, we include variables describing the household, such as household size and children aged 5 -9. Children aged 5 to 9 (*child)* are a hindrance in labour, as children of this age require constant supervision, compared to smaller children that can be carried while the work in completed. Therefore, in households with more young children, we would expect to see greater inefficiency as more time is occupied with household chores and child supervision. Likewise, households may also display a greater effect as women are often the main caregivers. Lastly, larger households are believed to have larger production power because of the greater labour supply available to the household. Therefore the greater the number of members, it the lower the observed inefficiency (*household size).*

Figure 2-2 depicts the yield distribution by ownership. It is evident that ownership impacts yields with different magnitudes across the distribution. Specifically, we find that on average yields on plots owned by women have a higher probability of producing low yields compared to plots that are owned by men. The difference in distribution may be present because of one of three main reasons: (1) female farmers cannot hedge the uncertain price of crops, (2) uneven land distribution (e.g. plot characteristics differ between plots), and (3) the net compensation status of a household depends on its size – smaller producers tend to be net buyers, and larger producers tend to be net sellers (Barrett 1993). Therefore, it is important to determine how these costs and barriers also vary across the yield distribution. Hence, to account for (and include) these distributional effects we compare plots with production below the 25th quintile to those that are producing above the 75th quintile in the upcoming econometric analysis.

**Table 2-5:** Definitions, descriptive statistics, and predicted signs for variables included in regression model.

| | Predicted Sign | Observa-tions | Mean | Standard Deviation | Minimum | Maximum | Variable Definition |
|---|---|---|---|---|---|---|---|
| Log Yields | | 8,223 | 6.8255 | 0.6143 | 5.0106 | 7.7187 | Log of harvested yields per plot in kg/ acre |
| Women Ownership | - | 8,223 | 0.0394 | 0.1946 | 0 | 1 | Sole women ownership of plot (1 = women owned, 0 = male owned) |
| Plot Size | - | 8,223 | 4.9835 | 10.6424 | 0.0001 | 125 | Plot size per acre |
| Topography 1 | + | 8,223 | 0.2640 | 0.4408 | 0 | 1 | Lowland topography of plot (1 = lowland, 0 = not) |
| Topography 2 | - | 8,223 | 0.5682 | 0.4954 | 0 | 1 | Midland topography of plot (1 = midland, 0 = not) |
| Topography 3 | - | 8,223 | 0.1678 | 0.3737 | 0 | 1 | Upland topography of plot (1 = |

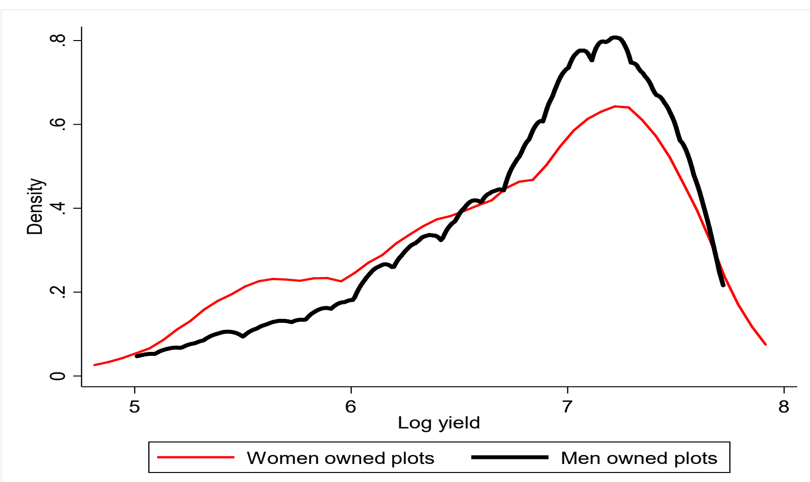
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | upland, 0 = not) |
| Crop 1 | + | 8,223 | 0.3080 | 0.4617 | 0 | 1 | Crop type grown on plot traditional rice variety (1 = traditional rice, 0 = not) |
| Crop 2 | + | 8,223 | 0.4739 | 0.4993 | 0 | 1 | Crop type grown on plot HY rice variety (1 = HY rice, 0 = not) |
| Crop 3 | + | 8,223 | 0.1913 | 0.3933 | 0 | 1 | Crop type grown on plot hybrid rice variety (1 = hybrid rice, 0 = not) |
| Crop 4 | - | 8,223 | 0.0268 | 0.1614 | 0 | 1 | Crop type grown on plot other (1 = other, 0 = not) |
| State 1 | - | 8,223 | 0.2296 | 0.4206 | 0 | 1 | Plot located in Bihar (1= Bihar, 0 = not) |
| State 2 | - | 8,223 | 0.3714 | 0.4832 | 0 | 1 | Plot located in Odisha (1= Odisha, 0 = not) |
| State 3 | - | 8,223 | 0.1867 | 0.3897 | 0 | 1 | Plot located in Uttar Pradesh (1= Uttar Pradesh, 0 = not) |
| State 4 | + | 8,223 | 0.2123 | 0.4090 | 0 | 1 | Plot located in West |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Bengal (1= West Bengal, 0 = not) |
| Child | - | 8,223 | 0.068 3 | 0.1117 | 0 | 0.6 | Share of children between the age od 5 – 9 in the household (0 = no children 5-9, 1 = only children 9-9) |
| WChild | - | 8,223 | 0.002 0 | 0.0209 | 0 | 0.4615 | Share of children 5-9 multiplied by women ownership |
| Caste | + | 8,223 | 0.304 8 | 0.4603 | 0 | 1 | Household high caste (1 = high caste,0 =low caste) |
| WCaste | + | 8,223 | 0.011 4 | 0.1063 | 0 | 1 | Household high caste multiplied by women ownership |
| Shock | + | 8,223 | 0.511 5 | 0.4999 | 0 | 1 | Plot experiencin g a drought in the 2014 growing season (1= drought,0 = none) |
| Wshock | + | 8,223 | 0.020 3 | 0.1411 | 0 | 1 | Plot drought multiplied by women ownership |
| Extension | + | 8,223 | 0.141 3 | 0.3484 | 0 | 1 | Women access to |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | extension services |
| WEducation | + | 8,200 | 0.2302 | 1.4863 | 0 | 17 | Educational level of household head multiplied by women ownership |
| Credit | + | 8,223 | 0.2855 | 0.4499 | 0 | 1 | Women access to credit services – formal or informal (1 = access, 0= no access) |
| WCredit | + | 8,223 | 0.0085 | 0.0919 | 0 | 1 | Women credit multiplied by women ownership |
| Household Size | + | 8,223 | 5.7715 | 2.5914 | 2 | 29 | Household size, number of members |

Note: The table provides information on all variables used in the study for both male and female owned plots.

**Figure 2-2**: Logged yield distribution by gender of plot owner, Eastern India, 2016




Note: The graph is a depiction of samples that fell between the 5% to 95% of the original distribution of yields. The graph was generated using kernel density estimations.

## 6. Estimation

Our approach to estimating the econometric model outlined in equation 1 is driven by two considerations. First, there are multiple effects considered in equation 1, including household fixed effects. Estimating the various fixed effects along with location variables using a binary variables (or a within regression framework) approach raises concerns regarding collinearity. More importantly, many of the coefficients that we estimate to address objective 2, are related to variables at the household level (e.g., caste, number of children in the household). Inclusion of household fixed effects would help identify the within-household efficiency of resource allocation which we seek to estimate under objective 1; but the household fixed effects would also sweep out the effect of any household level covariates that we include for testing hypotheses under objective 2.

We, therefore use a binary variable approach for estimating all fixed effects except for those at the household level. To account for household-specific effects ($\lambda_h$ in equation 1) we use a random effect specification, which accounts for variation across households and at the same time allows us to include household-level covariates.

Our second consideration concerns estimating heterogeneity in Pareto efficiency along the yield distribution and to evaluate if the marginal effect of covariates that are expected to mediate the level of efficiency. Such variables are expected to vary across the yield distribution. In this context conditional quantile regressions (Koenker and Bassett 1978) are not useful since they provide the impact of a variable on yields conditional on the explanatory variables. This is not meaningful in our context. We estimate Pareto efficiency across the yield distribution by using unconditional quantile regressions, which produce estimates of unconditional impacts of each covariate (e.g., gender) at different points of the yield distribution. Unconditional quantile regressions are more informative than either traditional regression and conditional quantile regression methods from a policy perspective (see Firpo, Fortin and Lemieux 2009 for details). The interpretation of coefficients at different quintiles, using this approach, is exactly the same as in a standard regression model, unlike conditional quantile regressions which provide conditional impacts. The distributional approach allows us to further isolate the mechanisms driving (in) efficiency. With the quintiles of interest being the 25$^{th}$ and 75$^{th}$; the 25$^{th}$ percentile is the bottom 25% of the yield distribution (the left tail of the distribution) and the 75$^{th}$ percentile is the top 25% of the yield distribution (the right tail of the distribution).

## 7. Results

In this section, we describe and discuss the main findings of the analysis conducted with respect to the objectives set out in the introduction. Table 2-6 reports the finding from the model outlined in equation 1. The models were aimed at evaluating the yield difference between men and women-owned plots. We present the results for seven different models in column 1 through 7 of the table. Where the first four models include the same baseline variables but vary in specification; model 1 presents a simple OLS regression, model 2 is a random effects model, model 3 limits the random effect model to the plots that fall below the 25$^{th}$ quintile in the yield distribution, while model 4 limits the random effect model to the plots above the 75$^{th}$ quintile. The remaining three models include additional variables to equation 1, aimed at examining the heterogeneity of the (in) efficiency across other influential variables and also vary in specification: model 5 is a random effects, model 6 limits the observations to the 25$^{th}$ quintile, and model 7 examines the 75$^{th}$ quantile.

We being by examining Pareto optimality and its prevalence in the data, with respect to both the simple and the extended model (model 1, 2, and 5). In doing so, we will gain an understanding of the (in) efficiencies observed on women-owned plots. Additionally, we will also explore the factors that have potentially amplified or mitigated such inefficiencies. We then further the analysis by examining the distributional effects that may play a role in the inefficiency that is ultimately observed (model 3, 4, 6, & 7). This provides us the opportunity to compare Pareto optimality on high and low yielding plots.

### 7.1 Pareto (in) efficiency

First, we focus on models 1, 2 and 3 to determine the effects of women's ownership on farm productivity measured by yields. We find that the coefficient on *women's ownership* is negative and significant across all three models (Table 2-6). The results support the conclusion that women-owned plots produce lower yields than plots owed by men and, thereby, indicating Pareto inefficiency in the allocation of household resources. When looking at model 1 we find an inefficiency of -15% on women-owned plots. However, accounting for household-level heterogeneity using a random effects specification (model 2), we find that the inefficiency is lowered from -15% to -7%. This result implies that approximately half of the original estimate of inefficiency was driven by household-level unobserved heterogeneity (model 1 & 2, row 1). However, when accounting for factors that may influence the Pareto optimality with our extended model that includes additional covariates, we find that the coefficient on women's ownership is -14% (model 5, row 1).

To account for the observed heterogeneity in Pareto efficiency (in yields), we added household caste (*caste*), access to extension services (*extension*), and credit markets (*credit*) to the model. We find that all variables positively and significantly influenced women's yields, however, the only variable to have a significant effect when interacted with women's ownership was caste (*WCaste*). Household caste (high caste=1) is associated with a 7% increase in yields, which increased to 12% on women-owned plots (model 5, row 13 & 14). Access to extension services also increased production by 8% (model 5, row 17). Though the positive effect of having credit access was lower (6%), it is still statistically significant (model 5, row 19). Thus both access to credit and extension services positively impact yields on both male and female plots.

Additionally, exogenous shocks (*shocks*), such as droughts, can decrease yields and also play a role in the determination of Pareto inefficiency. In these data, we find that droughts negatively impact yields (-28%), but the insignificance of the interaction of droughts and women's ownership suggests that households did not become more efficient during periods of stress due to the drought (model 5, row 15). Household controls for household head education (*WEducation*) and *household size* were also included in the extended model. However, they have an insignificant impact on yields (model 5, row 18 & 21).

In order to determine the effects of separability of the production and consumption side on the overall inefficiency recorded on women-owned plots, we include the number of children aged 5 – 9 in the household into the model (*child*). We find that the coefficient for children is negative in both the independent and interaction variable (*WChild*), but only the interaction is significant. Specifically, we observe a decrease in yields in women-owned plots by an additional 66% when children aged 5 – 9 are present in the household (model 5, row 12). This result is striking in that it shows that non-separability of consumption and production does not directly affect yields; however, it mediates inefficiencies and provides a possible explanation for departures in Pareto efficiency. Women (and their husbands) might strategically "neglect" plots farmed by women in the interests of allocating more time and labour resources to raising children. Note that in a model that assumes separability the role of such consumption side considerations on efficiency would not be found since production side variables like yields are assumed to be not affected by consumption side variables.

The control variable, *Plot size* has a negative and significant effect on yields (model 1, 2 & 5, row 2). This result is consistent with the commonly observed inverse productivity-size relationship in agricultural production. We find that the *topography* variables which represent the land type and general growing environmental also significantly affect yields. (models 1, 2 & 5, row 3 & 4). The coefficients on the *crop dummies* reveal that plots planted with rice crops produce higher yields than those planted with maize or legumes (model 1, 2 & 5, row 5, 6 & 7). Among the different types of rice crops grown in the region, we find that high yielding rice varieties produce the highest level of harvestable yields. Lastly, with respect to the location/ *state* of the plot, we find that West Bengal produces the highest yields compared to any other state.

### 7.2 Distributional effects of Pareto optimality

Our results show that Pareto inefficiency differs across the unconditional yield distribution, in both the simple and extended models. The coefficient on *women's ownership* is negative and significant for plots in the bottom quintiles of the yield distribution. Plots at the top of the yield distribution strikingly did not display any inefficiency (model 3, 4, 6, & 7). The Pareto inefficiency experienced from *women's ownership* at the bottom of the distribution ($25^{th}$ quintile) range from -18% to -38% across models (model 3 & 6, row 1). Thus, these findings signify that the inefficiencies are a more persistent problem in the left tail of the yield distribution, compared to either the top or the mean.[13]

We find that *caste* is a highly significant determinate of yield; where plots at the bottom of the yield distribution experience an increase of 8%, while plots at the top of the yield distribution experience an increase of 7% in yields (model 6, row 13). When looking at the joint effect of caste and women's ownership (through the caste interaction - *WCaste*), we find a notable deviation from the results of the mean model (model 5). For plots that fall below the 25th quintile on the yield distribution we find that being of a high caste positively impacts yields by 37% (model 5, row 14), but, when looking above the 75th quintile on the yield distribution we find that yields are negatively affected by 17% (model 6, row 14). This result may be attributed to the social norms and roles that are placed on women when they are of members of a high caste. High caste individual often face lower barriers and costs, as compared to individuals that are members of marginalized castes; therefore, when looking at less productive plots a higher yield for high caste is representative of these lower barriers. On the other hand, once an individual reaches a certain level of productivity, the role of women begins to shift. The drop in yields in highly productive households may arise from the fact that has households become wealthier, women are more likely to become housewives.

Additionally, the effect of access to extension services (*extension*) and *credit* may vary depending on the distribution. We find similar results to the mean model (model 5), where both have positive effects on yields, but significance is only observed when looking at plots at the bottom of the yield distribution. We find that extension services increase yields by 14% and

[13] The results from the models do not reflect figure 2-2 completely because in the models we are accounting for additional variables. Moreover, figure 2-2 is provided to show there is inefficiencies between male and female owned plots.

access to credit increases yields by 10% for plots that are at the bottom of the yield distribution (model 5, row 17 & 19). This may be due to the fact that low yielding plots need greater support to deal with costs and barriers they may face, while high yielding plots can independently carry most of the costs they face. With respect to drought (*shock*), we find that yields significantly decrease for both at the bottom and top of the yield distribution. Yields decrease by 47% and 20% respectively for low and high distributional plots (model 6 & 7, row, 15). Similarly to model 5, we do not observe a significant effect on women-owned plots. As in the mean model (model 5), we find that the household level control variables of household head's education and household size do not add to explanations of yield inefficiencies displayed in the $25^{th}$ and $75^{th}$ quintiles (model 6, row 18 & 21). Unlike in the case of the mean, we do not find any significant effects of the consumption side variable denoting the presence of small children in the household. Thus, we find that separability plays a minimal role at the mean but not at the tails of the yield distribution.

**Table 2-6:** Results for regression models of yield effects from equation 1, Eastern India, 2016

| | Model 1 (Baseline) | Model 2 (With household random effects) | Model 3 (25th quintile with household random effects) | Model 4 (75th quintile with household random effects) | Model 5 (Extended model) | Model 6 (25th quintile with household random effects) | Model 7 (75th quintile with household random effects) |
|---|---|---|---|---|---|---|---|
| *Women Own.* | -0.1534*** | -0.0750** | -0.1823** | -0.0265 | -0.1489** | -0.3828** | -0.0517 |
| | (0.032) | (0.036) | (0.074) | (0.033) | (0.074) | (0.153) | (0.070) |
| *Plot Size* | -0.0008 | -0.0014** | -0.0029** | -0.0004 | -0.0012* | -0.0026* | -0.0003 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| *Topography 2* | -0.0438*** | -0.0289** | -0.0685** | 0.0189 | -0.0429*** | -0.0996*** | 0.0091 |
| | (0.015) | (0.013) | (0.028) | (0.013) | (0.012) | (0.028) | (0.013) |
| *Topography 3* | -0.2862*** | -0.1557*** | -0.2975*** | -0.0611*** | -0.1396*** | -0.2662*** | -0.0456*** |
| | (0.020) | (0.015) | (0.035) | (0.016) | (0.015) | (0.035) | (0.016) |
| *Crop 1* | 0.2927*** | 0.2943*** | 0.4505*** | 0.0627** | 0.4491*** | 0.7254*** | 0.1761*** |
| | (0.040) | (0.031) | (0.070) | (0.032) | (0.032) | (0.071) | (0.032) |
| *Crop 2* | 0.5167*** | 0.4875*** | 0.8019*** | 0.1385*** | 0.6536*** | 1.0944*** | 0.2580*** |
| | (0.040) | (0.032) | (0.072) | (0.032) | (0.033) | (0.073) | (0.033) |
| *Crop 3* | 0.3850*** | 0.4220*** | 0.7310*** | 0.0129 | 0.5265*** | 0.9332*** | 0.0956*** |
| | (0.042) | (0.034) | (0.076) | (0.034) | (0.034) | (0.076) | (0.035) |
| *State 1* | -0.1076*** | -0.1304*** | -0.0753 | -0.2079*** | 0.0017 | 0.1261** | -0.1226*** |
| | (0.024) | (0.031) | (0.060) | (0.027) | (0.030) | (0.060) | (0.028) |
| *State 2* | -0.2916*** | -0.3226*** | -0.4123*** | -0.3178*** | -0.2206*** | -0.2653*** | -0.2392*** |
| | (0.019) | (0.026) | (0.050) | (0.023) | (0.026) | (0.051) | (0.024) |
| *State 3* | -0.4595*** | -0.4836*** | -0.7136*** | -0.3193*** | -0.3254*** | -0.4803*** | -0.2110*** |
| | (0.025) | (0.031) | (0.061) | (0.028) | (0.032) | (0.063) | (0.029) |
| *Child* | | | | | -0.103 | -0.0578 | -0.084 |
| | | | | | (0.072) | (0.139) | (0.065) |
| *W Child* | | | | | -0.6632* | -0.4636 | 0.2658 |
| | | | | | (0.379) | (0.768) | (0.354) |
| *Caste* | | | | | 0.0757*** | 0.0801** | 0.0744*** |
| | | | | | (0.019) | (0.037) | (0.017) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *WCaste* | | | | | 0.1281* | 0.3768** | -0.1731** |
| | | | | | (0.075) | (0.156) | (0.071) |
| *Shock* | | | | | -0.2853*** | -0.4708*** | -0.2055*** |
| | | | | | (0.014) | (0.030) | (0.014) |
| *WShock* | | | | | 0.0494 | 0.0694 | 0.0533 |
| | | | | | (0.060) | (0.130) | (0.059) |
| *Extension* | | | | | 0.0825*** | 0.1488*** | 0.0281 |
| | | | | | (0.025) | (0.048) | (0.022) |
| *WEducation* | | | | | 0.008 | 0.0216 | 0.0051 |
| | | | | | (0.007) | (0.015) | (0.007) |
| *Credit* | | | | | 0.0686*** | 0.1054*** | 0.0251 |
| | | | | | (0.019) | (0.036) | (0.017) |
| *WCredit* | | | | | 0.018 | -0.2051 | 0.0574 |
| | | | | | (0.083) | (0.172) | (0.079) |
| *Household Size* | | | | | 0.0009 | 0.0056 | 0.0012 |
| | | | | | (0.003) | (0.007) | (0.003) |
| *Constant* | 6.7183*** | 6.7167*** | 6.2099*** | 7.3970*** | 6.5700*** | 5.9523*** | 7.2925*** |
| | (0.043) | (0.038) | (0.081) | (0.037) | (0.042) | (0.088) | (0.040) |
| $\sigma_U$ *Constant* | | 0.5047*** | 0.941 | 0.430 | 0.4716*** | 0.8509*** | 0.4023*** |
| | | (0.007) | (0.007) | (0.001) | (0.006) | (-0.013) | (0.006) |
| $\sigma_e$ *Constant* | | 0.2688*** | 0.652 | 0.291 | 0.2684*** | 0.6557*** | 0.2909*** |
| | | (0.003) | (0.002) | (0.003) | (0.003) | (0.007) | (0.003) |
| *Observations* | 8223 | 8223 | 8223 | 8223 | 8200 | 8200 | 8200 |
| *r2* | 0.163 | 0.108 | 0.119 | 0.070 | 0.108 | 0.119 | 0.070 |

Note: The table represent the estimates for all the models run in this study. Yields is the dependent variables. Model 1 is a simple linear regression with the baseline variables, model 2 is a RE model with the baseline variables, model 3 is the RE marginal quantile regression for the $25^{th}$ quintile with the baseline variables, model 4 is the RE marginal quantile regression for the $75^{th}$ quintile with the baseline variables, model 5 is a RE model with the additional variables, model 6 is the RE marginal quantile regression for the $25^{th}$ quintile with the additional variables, model 7 is the RE marginal quantile regression for the $75^{th}$ quintile with the additional variables.

## 7.3 Additional Results

In our sample, the plot ownership variable displays limited variation; women own approximately 4% of the plots included in our sample, while male/ family ownership comprises the vast majority of plot ownership. The limited nature of women-owned plots may influence the validity of our result. To address the limitation, we run a bootstrap analysis. Specifically, we randomly select 100 observations from our data and rerun the RE baseline variable analysis 200 times. Table 2-7 presents the estimated coefficients, where we find qualitatively the same results as before. Specifically, we find that women ownership decreases yield by approximately 7%, a result consistent with that seen in table 6, model 2.

**Table 2-7**: Results for bootstrap random effects regression models of yield effects from equation 1, Eastern India, 2016

| | Estimates | Standard errors |
|---|---|---|
| | | |
| Women Ownership | -0.0747* | 0.0357*** |
| | (0.045) | (0.002) |
| Plot Size | -0.0014 | 0.0007*** |
| | (0.001) | (0.000) |
| Topography 2 | -0.0288** | 0.0127*** |
| | (0.014) | (0.000) |
| Topography 3 | -0.1553*** | 0.0154*** |
| | (0.020) | (0.000) |
| Crop 1 | 0.2944*** | 0.0313*** |
| | (0.074) | (0.001) |
| Crop 2 | 0.4873*** | 0.0320*** |
| | (0.067) | (0.001) |
| Crop 3 | 0.4223*** | 0.0344*** |
| | (0.074) | (0.001) |
| State 1 | -0.1306*** | 0.0308*** |
| | (0.029) | (0.000) |
| State 2 | -0.3226*** | 0.0263*** |
| | (0.016) | (0.000) |

| | | |
|---|---|---|
| State 3 | -0.4838*** | 0.0315*** |
| | (0.031) | (0.000) |
| Constant | 6.7167*** | 0.0377*** |
| | (0.068) | (0.001) |
| Observations | 8223 | 8223 |

Note: RE model with baseline variables bootstrap result with 100 sample size of 200 repetitions. Yields is the dependent variables.

## 8. Conclusion

In this study, we answered three objectives: we estimated whether rural Indian households achieve Pareto efficiency in the allocation of productive resources, examined the variation of the inefficiency across the distribution of yields, and evaluated if non-separable preferences play a role in the determination of the inefficiency. We found that rural households in eastern India do display inefficiencies in the allocation of resources, therefore, women's ownership of plots is seen to negatively impacts yields. The results of the study allow us to conclude that many observed and unobserved household characteristics influence the direction and magnitude of the inefficiency. Variables included to capture observed heterogeneity were shown to most efficiently mitigate the inefficiency; while shocks and the presence of young children substantially amplified the yield inefficiency.

Unobserved heterogeneity impacts the observed Pareto inefficiency. We find that households at the bottom of the yield distribution face greater limitations compared to households at the top. This result is most prominent when looking at the effects of women's ownership. Plots that fall within the top of the yield distribution do not display significant inefficiency in the allocation of resources between women and men-owned plots.

Lastly, with respect to our last objective aimed at evaluating non-separable preferences, we find that the non-separability of consumption and production does not directly affect yields. In this study, we find that on plots owned by women that have children aged 5 – 9 yields significantly decrease. This result provides a possible explanation for departures in Pareto efficiency.

Overall, the difference in yields may be a result of three main factors. Firstly, the difference is rooted in individual control over plots and how individuals gain this control may play a role in the resources used during production. This problem of resource and labour allocation may ultimately be a function of the power the individual owner possesses within the household. In the context of this study, women in India display a much lower level of household power, thus the yield differential reflects that as women-owned plots also have (on average) lower yields than men-owned plots. Additionally, the lack of markets may also influence yields as missing land markets have the potential to interfere with the allocation of resources within the household. Lastly, the information asymmetry within a household may also influence yields across plots. The operator of the plot may be unaware of the labour resources available, and the amount of labour required. Therefore, taken together these reasons may be explanations for the difference in yields.

Moreover, this study contributes to the current body of literature and research that seeks to examine inefficiencies in the household. The results of the study build on previous studies in an effort to further understand the mechanism driving the inequalities frequently observed between men and women. In this study we explore alternative options that increase and decrease the Pareto inefficiencies, specifically, we find that several household-level characteristics like number of children and caste play a role in the determination of the effect. This is important because in order to provide policy measures that address these inefficiencies it is imperative to understand the mechanism driving the differences of those in need.

All in all, this study provides support for the proposition by the FAO that increasing yields on land farmed by women up to levels achieved by men would increase total agricultural output in developing countries. Thus, this study also support an increase in investments directed towards agriculture. Investments in this area aid in the achievement of many persistent problems and the importance of investments in reflected in the goals of many SDG's. Increases in the agricultural sector have the potential to decrease poverty because many of the rural poor are heavily dependent on agriculture. Agriculture also plays a role in attaining gender equality. Women are heavily involved in the sector, thus increases in the livelihoods of agricultural dependent individuals would disproportionately help women, as women are also often lower on the social ladder. Finally, as shown by the results of the study, investments in agriculture would help decrease the Pareto inefficiency observed in the household. This is because a more efficient agricultural sector would result in more resources, more information, and more production – all of which can help decrease the inefficiency.

## 9. References


Adeleke, O. a., O.I. Adesiyan, O. a. Olaniyi, K.O. Adelalu, and H.M. Matanmi. 2008. "Gender differentials in the productivity of cereal crop farmers: A case study of maize farmers in Oluyole local government area of Oyo State." *Agricultural Journal* 3(3):193–198.

Akresh, R. 2008. "(In)Efficiency in Intrahousehold Allocations."

Akresh, R. 2005. "Understanding Pareto Inefficient Intrahousehold Allocations." (1858).

Apps, P.F., and R. Rees. 1996. "Labour supply, household production and intra-family welfare distribution." *Journal of Public Economics* 60(2):199–219.

Bain, C. 2011. "Gendering Agricultural Aid." 25(1):48–74.

Barrett, C.B., M.F. Bellemare, and J.Y. Hou. 2010. "Reconsidering Conventional Explanations of the Inverse Productivity-Size Relationship." *World Development* 38(1):88–97. Available at: http://dx.doi.org/10.1016/j.worlddev.2009.06.002.

Bobonis, G.J. 2009. "Is the Allocation of Resources within the Household Efficient? New Evidence from a Randomized Experiment." *Journal of Political Economy* 117(3):453–503.

Bourguignon, F., M. Browning, P.A. Chiappori, and V. Lechene. 1993. "Intra Household Allocation of Consumption: A Model and Some Evidence from French Data." *Annales d'Économie et de Statistique* (29):137–156.

Browning, M., P.A. Chiappori, and Y. Weiss. 2007. *Family Economics*. Cambridge: Cambridge University Press.

Buehren, N., M. Goldstein, E. Molina, and J. Vaillant. 2017. "The Impact of Strengthening Agricultural Extension Services: Evidence from Ethiopia." *World Bank Policy Research Working Paper 8169* (August):28. Available at: econ.worldbank.

Bunch, S., and R. Mehra. 2008. "Women help solve hunger: Why is the world still waiting?" *International Center for Research on Women (ICRW)*.

Carr, E.R. 2008. "Men's crops and women's crops: The importance of gender to the understanding of agricultural and development outcomes in Ghana's Central Region." *World Development* 36(5):900–915.

Chiappori, P.-A. 1997. "Introducing Household Production in Collective Models of Labor Supply." *Journal of Political Economy* 105(1):191–209.

Chiappori, P., B. Fortin, and G. Lacroix. 2002. "Marriage Market, Divorce Legislation, and Household Labor Supply." *Journal of Political Economy* 110(1):37–72.

Chiappori, P., and Y. Weiss. 2007. "Divorce, Remarriage, and Child Support." *Journal of Labor Economics* 25(1):37–74.

Christiaensen, L., L. Demery, and J. Kuhl. 2011. "The (evolving) role of agriculture in poverty reduction: an empirical perspective." *Journal of Development Economics* 96(2):239–254.

Couprie, H. 2007. "Time allocation within the family: Welfare implications of life in a couple." *Economic Journal* 117(516):287–305.

Dercon, S. 2009. "Rural Poverty: Old Challenges in New Contexts." *World Bank Research Observer* 24(1):1–28.

Doss, C., C. Kovarik, A. Peterman, A. Quisumbing, and M. van den Bold. 2015. "Gender inequalities in ownership and control of land in Africa: Myth and reality." *Agricultural Economics (United Kingdom)* 46(3):403–434.

Doss, C.R. 2018. "Women and agricultural productivity: Reframing the Issues." *Development Policy Review* 36(1):35–50.

Doss, C.R., and M.L. Morris. 2000. "How does gender affect the adoption of agricultural innovations?" *Agricultural Economics* 25(1):27–39.

Duflo, E. 2000. "Grandmothers and Graddaughters: Old Age Pension and Intra-Household Allocation in South Africa." *The World Bank Economic Review* 17(1):1–25.

Duncan, B.A., and C. Brants. 2004. "ACCESS TO AND CONTROL OVER LAND FROM A GENDER PERSPECTIVE A STUDY CONDUCTED IN THE VOLTA REGION OF GHANA." Available at: http://www.fao.org/3/ae501e/ae501e00.htm.

Ellis, F. 2005. "Small-Farms, Livelihood Diversification and Rural-Urban Transitions: Strategic Issues in Sub-Saharan Africa." In *FPRRI Research Workshop on The Future of Small Farms*. Available at: http://www.uea.ac.uk/polopoly_fs/1.53421!2005 future small farms.pdf.

Firpo, S., N.M. Fortin, and T. Lemieux. 2009. "Unconditional Quantile Regressions." *Econometrica* 77(3):953–973.

Gates, M.F. 2014. "Putting women and girls at the center of development." *Science* 345(6202):1273–1275.

Gupta, G. 2009. "When women farm, crops and economies grow."

Harper, C., K. Nowacka, H. Alder, and G. Ferrant. 2014. "Measuring women's empowerment and social transformation in the post-2015 agenda." Available at: https://www.odi.org/publications/8257-measuring-womens-empowerment-and-social-transformation-post-2015-agenda [Accessed April 1, 2019].

HLPE. 2016. "Sustainable agricultural development for food security and nutrition: HLPE High Level Panel of Experts what roles for livestock?" *FAO* (10):140. Available at: http://www.fao.org/3/am307e/am307e00.pdf.

Hurni, H., and B. Osman-Elasha. 2009. "Context, conceptual framework and sus- tainability indicators. In Agriculture at a crossroads: Global report."

de Janvry,  by A., M. Fafchamps, and E. Sadoulet. 1991. "Peasant Household Behavior with Missing Markets: Some Paradoxes Explain." Available at: https://ageconsearch.umn.edu/record/198579/files/agecon-cal-578.pdf.

Kelkar, G. 2009. "the Feminization of Agriculture in Asia : Implications for Women ' S Agency and Productivity." :1–16.

Koenker, R., and G. Bassett. 1978. "Regression Quantiles Author ( s ): Roger Koenker , Gilbert Bassett and Jr . Published by : The Econometric Society Stable URL : https://www.jstor.org/stable/1913643 The Econometric Society is collaborating with JSTOR to digitize , preserve and extend acce." *Econometrica* 46(1):33–50.

Kraay, A. 2006. "When Is Growth Pro-Poor? Evidence from a Panel of Countries." *Journal of Development Economics* (80):198–227.

M. Browning, and P.A. Chiappori. 1998. "Efficient Intra-Household Allocations: A General Characterization and Empirical Tests." *Econometrica* 66(6):1241–1278.

Manser, M., and M. Brown. 1980. "Marriage and household decision making: a bargaining analysis." *International Economic Review* 21(1):31–44.

Mohapatra, S., and M.K. Luckert. 2014. "Educational returns beyond the mean: Differences along wage distributions of men and women in India's formal labor market." *International Journal of Educational Development* 36:22–32. Available at: http://dx.doi.org/10.1016/j.ijedudev.2014.01.002.

Moock, P.R. 1976. "The Efficiency of Women as Farm Managers: Kenya." *American Journal of Agricultural Economics* 58(5):831–835.

Owens, J. 2001. *Gender-Differentiated Household Resource Allocation: Empirical Evidence in Sene- gal*. Michigan State University.

Parveen, S. 2008. "Access of Rural Women to Productive Resources in Bangladesh: A Pillar for Promoting their Empowerment." *International Journal of Rural Studies (IJRS)* 15(1):1–8. Available at: www.ivcs.org.uk/IJRS.

Rangel, M.A., and D. Thomas. 2012. "Gender , Production and Consumption : Allocative Efficiency within Farm Households."

Ravallion, M., and S. Chen. 2003. "Measuring Pro-Poor Growth." *Economics Letters* (78):93–9.

Reserve Bank of Inida. 2013. "Number and Percentage of Population Below Poverty Line." Available at: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=15283.

Sachs, C. 1996. "Gendered fields: Rural women, agriculture, and environment."

Saito, K.A., H. Mekonnen, and D. Spurling. 1994. *Raising the productivity of women farmers in sub-saharan Africa*. The World Bank.

Schultz, T.P. 2001. "WOMEN ' S ROLES IN THE AGRICULTURAL HOUSEHOLD :

BARGAINING AND HUMAN CAPITAL INVESTMENTS Contents Abstract 2 . Models of individual and family economic behavior 5 . Investment in women ' s human capital : Measuring returns 6 . Conclusions and direction fo." In *Handbook of Agricultural Economics*. pp. 384–443.

Singh, I., L. Squire, and J. Strauss. 1986. "Agricultural Household Models: Extensions, Applications, and Policy."

SOFA. 2011. *The State of Food and Agriculture: Women in Agircutlure, closing the Gender Gap for Development*. Available at: http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00010694-195505000-00019.

SOFA, and C. Doss. 2011. "The role of women in agriculture." No. 11–02,

Thomas, D., and C.L. Chen. 1994. "Income shares and shares of income: empirical tests of models of household resource allocation." No. 94–08,

Udry, C. 1996. "Gender, Agricultural Production, and the Theory of the Household." *Journal of Political Economy* 104(5):1010–1046.

United Nations. 2005. "The Millennium Development Goals Report." Available at: https://unstats.un.org/unsd/mi/pdf/MDG Book.pdf.

Vargas Hill, R., and M. Vigneri. 2011. "Mainstreaming gender sensitivity in cash crop market supply chains." Available at: www.fao.org/economic/esa.

World Bank. 2011. "Gender Equality and Development." Available at: https://siteresources.worldbank.org/INTWDR2012/Resources/7778105-1299699968583/7786210-1315936222006/Complete-Report.pdf.

World Bank. 2018. "India States Briefs." Available at: http://www.worldbank.org/en/news/feature/2016/05/26/india-states-briefs.

World Bank. 2007. "World Development Report 2008: Agriculture for Development."

World Bank, Food Agriculture Organization (FAO), and International Fund for Agricultural Development (IFAD). 2009. "Gender in agriculture sourcebook."

World Economic Forum. 2018. *The Global Gender Gap Report*. Available at: https://www.weforum.org/reports/the-global-gender-gap-report-2018 .

Yamano, T. 2015. "Rice Monitoring Survey: South Asia." Available at: http://ricestat.irri.org/fhsd/php/panel.php.

Yamano, T., P. Veetil, I. Gupta, J. Johny, D. Villanueva, P. Ricarte, and H. Valera. 2017. "Rice Monitoring Survey 2016 in India."

## References

Adeleke, O. a., O.I. Adesiyan, O. a. Olaniyi, K.O. Adelalu, and H.M. Matanmi. 2008. "Gender differentials in the productivity of cereal crop farmers: A case study of maize farmers in Oluyole local government area of Oyo State." *Agricultural Journal* 3(3):193–198.

Agénor, P. 2006. "Discussion Paper Series A Theory of Infrastructure-led Development Download paper from : of Infrastructure-Led Development." Centre for Growth and Business Cycle Research (083). Available at: http://linkinghub.elsevier.com/retrieve/pii/S0165188910000102.

Aggarwal, S. 2018. "Do rural roads create pathways out of poverty? Evidence from India." *Journal of Development Economics* 133(January):375–395. Available at: https://doi.org/10.1016/j.jdeveco.2018.01.004.

Akresh, R. 2005. "Understanding Pareto Inefficient Intrahousehold Allocations." (1858).

Akresh, R. 2008. "(In)Efficiency in Intrahousehold Allocations."

Alderman, H., P.A. Chiappori, L. Haddad, J. Hoddinott, and R. Kanbur. 1995. "Unitary vs Collective Models of the household: Is it time to shift the burden of proof?" The World Bank Research Observer 10(1):1–19.

Ali, I., and Z.A. Hatta. 2012. "Women's Empowerment or Disempowerment through Microfinance: Evidence from Bangladesh." Asian Social Work and Policy Review 6(2):111–121.

Alkire, S., R. Meinzen-Dick, A. Peterman, A.R. Quisumbing, G. Seymour, and A. Vaz. 2012. "'The Women's Empowerment in Agriculture Index,' Poverty, Health & Nutrition Division, International Food Policy Research Institute, IFPRI Discussion Paper No. 01240, December 2012. http://www.ifpri.org/publication/women-s-empowerment-agriculture-index."

Ambler, K., and A. De Brauw. 2017. "The Impacts of Cash Transfers on Women's Empowerment." World Bank Group Soical Protection and Labour (1702).

Apps, P.F., and R. Rees. 1996. "Labour supply, household production and intra-family welfare distribution*." Journal of Public Economics* 60(2):199–219.

Asher, S., and P. Novosad. 2015. "The Employment Effects of Road Construction in Rural India."

Asher, S., and P. Novosad. 2017. "Rural Roads and Structural Transformation." Available at: http://www.dartmouth.edu/~novosad/asher-novosad-roads.pdf.

Asian Development Bank. 2018. "Outlook 2018 Update - MAINTAINING STABILITY AMID HEIGHTENED UNCERTAINTY."

Athey, S., and G. Imbens. 2015. "Recursive Partitioning for Heterogeneous Causal Effects."

National Academy of Sciences of the United States of America 113(27):7353–7360. Available at: http://arxiv.org/abs/1504.01132.

Bain, C. 2011. “Gendering Agricultural Aid.” 25(1):48–74.

Barrett, C.B., M.F. Bellemare, and J.Y. Hou. 2010. “Reconsidering Conventional Explanations of the Inverse Productivity-Size Relationship.” *World Development* 38(1):88–97. Available at: http://dx.doi.org/10.1016/j.worlddev.2009.06.002.

Bell, C. 2010. “Goods, Education and Health: A Combined Model for Evaluating PMGSY.”

Bertocchi, G., M. Brunetti, and C. Torricelli. 2014. “Who holds the purse strings within the household? The determinants of intra-family decision making.” *Journal of Economic Behavior and Organization* 101(2014):65–86. Available at: http://dx.doi.org/10.1016/j.jebo.2014.02.012.

Besley, T., and Burgess. 2003. “Halving Global Poverty.” Journal of Economic Perspectives 17(3):2–22.

Bobonis, G.J. 2009. “Is the Allocation of Resources within the Household Efficient? New Evidence from a Randomized Experiment.” *Journal of Political Economy* 117(3):453–503.

Bourguignon, F., M. Browning, P.A. Chiappori, and V. Lechene. 1993. “Intra Household Allocation of Consumption: A Model and Some Evidence from French Data.” Annales d’Économie et de Statistique (29):137–156.

Browning, M., P.A. Chiappori, and Y. Weiss. 2007. Family Economics. Cambridge: Cambridge University Press.

Browning, M., P.A. Chiappori, and Y. Weiss. 2007. Family Economics. Cambridge: Cambridge University Press.

Bryan, G., S. Chowdury, and A.M. q Mobarak. 2014. “Underinvestment in a Profitable Technology: The Case of Seasonal Migration in Bangladesh.” Econometrica 82(5):1671–1748. Available at: http://doi.wiley.com/10.3982/ECTA10489.

Buehren, N., M. Goldstein, E. Molina, and J. Vaillant. 2017. “The Impact of Strengthening Agricultural Extension Services: Evidence from Ethiopia.” World Bank Policy Research Working Paper 8169 (August):28. Available at: econ.worldbank.

Bunch, S., and R. Mehra. 2008. “Women help solve hunger: Why is the world still waiting?” International Center for Research on Women (ICRW).

Card, D. 2001. “Estimating the return to schooling: Progress on some persistent econometric problems.” *Econometrica* 69(5):1127–1160.

Carr, E.R. 2008. “Men’s crops and women’s crops: The importance of gender to the understanding of agricultural and development outcomes in Ghana’s Central Region.” World Development 36(5):900–915.

Chiappori, P., and Y. Weiss. 2007. "Divorce, Remarriage, and Child Support." Journal of Labor Economics 25(1):37–74.

Chiappori, P., B. Fortin, and G. Lacroix. 2002. "Marriage Market, Divorce Legislation, and Household Labor Supply." Journal of Political Economy 110(1):37–72.

Chiappori, P.-A. 1997. "Introducing Household Production in Collective Models of Labor Supply." Journal of Political Economy 105(1):191–209.

Christiaensen, L., L. Demery, and J. Kuhl. 2011. "The (evolving) role of agriculture in poverty reduction: an empirical perspective." Journal of Development Economics 96(2):239–254.

Cook, T.D., and W. Shadish. 2012. "DESIGN AND ANALYSIS OF PRACTICAL QUASI-EXPERIMENTS FOR USE IN EDUCATION RESEARCH." Institute for Policy Research (IPR) Northwestern University. Available at: https://www.ipr.northwestern.edu/workshops/past-workshops/quasi-experimental-design-and-analysis-in-education/quasi-experiments/docs/QE-Day2.pdf.

Couprie, H. 2007. "Time allocation within the family: Welfare implications of life in a couple." Economic Journal 117(516):287–305.

de Janvry,  by A., M. Fafchamps, and E. Sadoulet. 1991. "Peasant Household Behavior with Missing Markets: Some Paradoxes Explain." Available at: https://ageconsearch.umn.edu/record/198579/files/agecon-cal-578.pdf.

Dercon, S. 2009. "Rural Poverty: Old Challenges in New Contexts." World Bank Research Observer 24(1):1–28.

Dollar, D., and A. Kraay. 2002. "Growth Is Good for the Poor." Journal of Economic Growth 7(3):195–225.

Donaldson, D. 2018. "Railroads of the Raj: Estimating the Impact of." American Economic Review 108(4–5):899–934.

Doss, C., C. Kovarik, A. Peterman, A. Quisumbing, and M. van den Bold. 2015. "Gender inequalities in ownership and control of land in Africa: Myth and reality." Agricultural Economics (United Kingdom) 46(3):403–434.

Doss, C.R. 2018. "Women and agricultural productivity: Reframing the Issues." Development Policy Review 36(1):35–50.

Doss, C.R., and M.L. Morris. 2000. "How does gender affect the adoption of agricultural innovations?" Agricultural Economics 25(1):27–39.

Doss, C.R., and M.L. Morris. 2000. "How does gender affect the adoption of agricultural innovations?" Agricultural Economics 25(1):27–39.

Duflo, E. 2000. "Grandmothers and Graddaughters: Old Age Pension and Intra-Household Allocation in South Africa." The World Bank Economic Review 17(1):1–25.

Duflo, E. 2000. “Grandmothers and Graddaughters: Old Age Pension and Intra-Household Allocation in South Africa.” The World Bank Economic Review 17(1):1–25.

Duflo, E. 2012. “Women Empowerment and Economic Development.” Journal of Economic Literature 50(4):1051–1079.

Duncan, B.A., and C. Brants. 2004. “ACCESS TO AND CONTROL OVER LAND FROM A GENDER PERSPECTIVE A STUDY CONDUCTED IN THE VOLTA REGION OF GHANA.” Available at: http://www.fao.org/3/ae501e/ae501e00.htm.

Ellis, F. 2005. “Small-Farms, Livelihood Diversification and Rural-Urban Transitions: Strategic Issues in Sub-Saharan Africa.” In FPRRI Research Workshop on The Future of Small Farms. Available at: http://www.uea.ac.uk/polopoly_fs/1.53421!2005 future small farms.pdf.

Filmer, D. 2005. “Gender and wealth disparities in schooling: Evidence from 44 countries.” International Journal of Educational Research 43(6):351–369.

Firpo, S., N.M. Fortin, and T. Lemieux. 2009. “Unconditional Quantile Regressions.” Econometrica 77(3):953–973.

Frey, C.B., and M.A. Osborne. 2017. “The future of employment: how susceptible are jobs to computerisation?” Technological forecasting and social change 114:254–280.

Ganle, J.K., K. Afriyie, and A.Y. Segbefia. 2015. “Microcredit: Empowerment and disempowerment of rural women in Ghana.” World Development 66:335–345. Available at: http://dx.doi.org/10.1016/j.worlddev.2014.08.027.

Gates, M.F. 2014. “Putting women and girls at the center of development.” Science 345(6202):1273–1275.

Gates, M.F. 2014. “Putting women and girls at the center of development.” Science 345(6202):1273–1275.

Ghosh, M. 2017. “Infrastructure and Development in Rural India.” Margin- The Journal of Applied Economic Research 11(3):256–289.

Gibbs, A., S. Willan, A. Misselhorn, and J. Mangoma. 2012. “Combined structural interventions for gender equality and livelihood security: A critical review of the evidence from southern and eastern Africa and the implications for young people.” Journal of the International AIDS Society 15(Suppl 1).

Government of India. “Area & Population.” Available at: http://censusindia.gov.in/Census_And_You/area_and_population.aspx [Accessed April 3, 2019].

Government of India. 2012. “PRADHAN MANTRI GRAM SADAK YOJANA - Programme Guidelines.”

Griliches, Z. 2006. “Estimating the Returns to Schooling: Some Econometric Problems.” Econometrica 45(1):1.

Gupta, G. 2009. “When women farm, crops and economies grow.”

Harper, C., K. Nowacka, H. Alder, and G. Ferrant. 2014. “Measuring women’s empowerment and social transformation in the post-2015 agenda.” Available at: https://www.odi.org/publications/8257-measuring-womens-empowerment-and-social-transformation-post-2015-agenda [Accessed April 1, 2019].

Harper, C., K. Nowacka, H. Alder, and G. Ferrant. 2014. “Measuring women’s empowerment and social transformation in the post-2015 agenda.” Available at: https://www.odi.org/publications/8257-measuring-womens-empowerment-and-social-transformation-post-2015-agenda [Accessed April 1, 2019].

Hashemi, S., R.S. Schuler, and A.P. Riley. 1996. “Rural credit programs and women’s empowerment in Bangladesh.” World Development 24(4):635–653.

HLPE. 2016. “Sustainable agricultural development for food security and nutrition: HLPE High Level Panel of Experts what roles for livestock?” FAO (10):140. Available at: http://www.fao.org/3/am307e/am307e00.pdf.

Hurni, H., and B. Osman-Elasha. 2009. “Context, conceptual framework and sus- tainability indicators. In Agriculture at a crossroads: Global report.”

Husain, Z., D. Mukherjee, and M. Dutta. 2014. “Self Help Groups and empowerment of women: Self-selection or actual benefits.” Journal of International Development 26(4):422–437.

Imbens, G., and T. Lemieux. 2007. “REGRESSION DISCONTINUITY DESIGNS: A GUIDE TO PRACTICE.”

Jacob, R.T., P. Zhu, M.-A. Somers, and H. Bloom. 2012. “A Practical Guide to Regression Discontinuity.” MDRC Building Knowledge to Improve Soical Policy (July):1–100. Available at: http://www.mdrc.org/practical-guide-regression-discontinuity.

Kelkar, G. 2009. “the Feminization of Agriculture in Asia : Implications for Women ’ S Agency and Productivity.” :1–16.

Koenker, R., and G. Bassett. 1978. “Regression Quantiles Author ( s ): Roger Koenker , Gilbert Bassett and Jr . Published by : The Econometric Society Stable URL : https://www.jstor.org/stable/1913643 The Econometric Society is collaborating with JSTOR to digitize , preserve and extend acce.” Econometrica 46(1):33–50.

Kraay, A. 2006. “When Is Growth Pro-Poor? Evidence from a Panel of Countries.” Journal of Development Economics (80):198–227.

Lehne, J., J.N. Shapiro, and O. V Eynde. 2018. “Building connections: Political corruption and road construction in India.” Journal of Development Economics 131(2018):62–78. Available at: http://dx.doi.org/10.1016/j.jdeveco.2017.10.009.

Lemieux, T. 2011. “Lecture 1 : Introduction to Regression Discontinuity Designs in Economics Plan of the three lectures on regression discontinuity designs.” University of Coimbra.

M. Browning, and P.A. Chiappori. 1998. “Efficient Intra-Household Allocations: A General Characterization and Empirical Tests.” Econometrica 66(6):1241–1278.

Mahmud, M., and Y. Sawada. 2018. “Infrastructure and well-being: employment effects of Jamuna bridge in Bangladesh.” Journal of Development Effectiveness 10(3):327–340. Available at: https://www.tandfonline.com/doi/full/10.1080/19439342.2018.1483415.

Manser, M., and M. Brown. 1980. “Marriage and household decision making: a bargaining analysis.” International Economic Review 21(1):31–44.

McCrary, J. 2008. “Manipulation of the running variable in the regression discontinuity design: A density test.” Journal of Econometrics 142(2):698–714. Available at: http://www.sciencedirect.com/science/article/pii/S0304407607001133%5Cnhttp://www.sciencedirect.com/science?_ob=MiamiImageURL&_cid=271689&_user=486651&_pii=S0304407607001133&_check=y&_origin=article&_zone=toolbar&_coverDate=29-Feb-2008&view=c&originContent.

Mellor, J.W. 2017. Agricultural Development and Economic Transformation: Promoting Growth with Poverty Reduction.

ModU. 2015. “Your guide to regression discontinuity module.” Social Science Research Institute Duke University. Available at: https://modu.ssri.duke.edu/module/your-guide-regression-discontinuity [Accessed April 29, 2019].

Mohapatra, S., and M.K. Luckert. 2014. “Educational returns beyond the mean: Differences along wage distributions of men and women in India’s formal labor market.” International Journal of Educational Development 36:22–32. Available at: http://dx.doi.org/10.1016/j.ijedudev.2014.01.002.

Monitoring and Accounting System (OMMAS). “PRADHAN MANTRI GRAM SADAK YOJANA.” Available at: http://omms.nic.in/ [Accessed April 3, 2019].

Montenegro, M. 2016. Land Rights and Women ’ s Empowerment in Rural Peru : Insights from Item Response Theory. University of Alberta.

Moock, P.R. 1976. “The Efficiency of Women as Farm Managers: Kenya.” American Journal of Agricultural Economics 58(5):831–835.

Morten, M., J. Oliveira, T. Allen, M. Alsan, A. Barufi, G. Bryan, K. Casey, A. Chandrasekhar, R. Dix-Carneiro, D. Donaldson, T. Dinkelman, P. Dupas, F. Finan, D. Fitzger-Ald, P. Gertler, D. Gollin, S. Jha, B. Kovak, K. Mangum, A. Minian, M. Mobarak, D. Mckenzie, P. Pereda, N. Qian, S. Redding, M. Rosenzweig, and S. Schulhofer-Wohl. 2018. “The Effects of Roads on Trade and Migration: Evidence from a Planned Capital City.” Available at: https://web.stanford.edu/~memorten/ewExternalFiles/Morten_Oliveira_Brasilia.pdf.

Moser, C.O. 2012. Gender planning and development: Theory, practice and training. Routledge.

OECD. 2014. “Gender Equality: Balancing paid work, unpaid work and leisure.” Available at: http://www.oecd.org/gender/data/balancingpaidworkunpaidworkandleisure.htm [Accessed April 1, 2019].

Owens, J. 2001. Gender-Differentiated Household Resource Allocation: Empirical Evidence in Sene- gal. Michigan State University.

Ozier, O. 2011. “The Impact of Secondary Schooling in Kenya : A Regression Discontinuity Analysis.” Policy Research Working Paper 30(January):1869–1878. Available at: http://economics.ozier.com/owen/papers/ozier_JMP_20110117.pdf.

Parveen, S. 2008. “Access of Rural Women to Productive Resources in Bangladesh: A Pillar for Promoting their Empowerment.” International Journal of Rural Studies (IJRS) 15(1):1–8. Available at: www.ivcs.org.uk/IJRS.

Pattison, J.K. 2017. Margins in the Mountains: Poverty Dynamics in India’s Western and Eastern Ghats.

Paul Schultz, T. 2002. “Why governments should invest more to educate girls.” World Development 30(2):207–225.

Rahman, L., and V. Rao. 2004. “The Determinants of Gender Equity in India: Examining Dyson and Moore’s Thesis with New Data.” Population and Development Review 30(2):239–268.

Rangel, M.A., and D. Thomas. 2012. “Gender , Production and Consumption : Allocative Efficiency within Farm Households.”

Ravallion, M. 2001. “Growth Inequality and Poverty: Looking beyond Averages.” World Development 29(11):1803–1815.

Ravallion, M., and S. Chen. 2003. “Measuring Pro-Poor Growth.” Economics Letters (78):93–9.

Reserve Bank of Inida. 2013. “Number and Percentage of Population Below Poverty Line.” Available at: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=15283.

Reserve Bank of Inida. 2013. “Number and Percentage of Population Below Poverty Line.” Available at: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=15283.

Sachs, C. 1996. “Gendered fields: Rural women, agriculture, and environment.”

Saito, K.A., H. Mekonnen, and D. Spurling. 1994. Raising the productivity of women farmers in sub-saharan Africa. The World Bank.

Salia, S., J. Hussain, I. Tingbani, and O. Kolade. 2018. “Is women empowerment a zero sum game? Unintended consequences of microfinance for women’s empowerment in Ghana.” International Journal of Entrepreneurial Behavior & Research 24(1):273–289.

Schultz, T.P. 2001. “WOMEN ’ S ROLES IN THE AGRICULTURAL HOUSEHOLD : BARGAINING AND HUMAN CAPITAL INVESTMENTS Contents Abstract 2 . Models of individual and family economic behavior 5 . Investment in women ’ s human capital :

Measuring returns 6 . Conclusions and direction fo.” In Handbook of Agricultural Economics. pp. 384–443.

Shamdasani, Y. 2018. “Rural Road Infrastructure and Agricultural Production: Evidence from India.”

Sharma, S. 2016. “Achieving Gender Equality in India: What Works, and What Doesn’t.” United Nations University. Available at: https://unu.edu/publications/articles/achieving-gender-equality-in-india-what-works-and-what-doesnt.html.

Singh, I., L. Squire, and J. Strauss. 1986. “Agricultural Household Models: Extensions, Applications, and Policy.”

Singh, I., L. Squire, and J. Strauss. 1986. “Agricultural Household Models: Extensions, Applications, and Policy.”

Skoufias, E. 1993. “Labor market opportunities and intrafamily time allocation in rural households in South Asia.” Journal of Development Economics 40(2):277–310.

Smith, L.C., and L. Haddad. 2015. “Reducing Child Undernutrition: Past Drivers and Priorities for the Post-MDG Era.” World Development 68(1):180–204. Available at: http://dx.doi.org/10.1016/j.worlddev.2014.11.014.

SOFA, and C. Doss. 2011. “The role of women in agriculture.” No. 11–02,

SOFA. 2011. The State of Food and Agriculture: Women in Agircutlure, closing the Gender Gap for Development. Available at: http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00010694-195505000-00019.

Sveiby, K.-E., P. Gripenberg, B. Segercrantz, A. Eriksson, and A. Aminoff. 2009. “The Unintended and Undesirable Consequences of Innovation.” In XX ISPIM conference The Future of Innovation Vienna.

Thomas, D., and C.L. Chen. 1994. “Income shares and shares of income: empirical tests of models of household resource allocation.” No. 94–08,

Tomich, T. P., Kilby, P., Johnston, B. F., & Izumida, Y. 1997. “Transforming agrarian economies: Opportunities seized, opportunities missed.” Developing Economies 35(3):338–330.

Udry, C. 1996. “Gender, Agricultural Production, and the Theory of the Household.” Journal of Political Economy 104(5):1010–1046.

UN Women. 2018. “Facts and Figures: Economic Empowerment.” Available at: http://www.unwomen.org/en/what-we-do/economic-empowerment/facts-and-figures [Accessed April 1, 2019].

United Nations Development Programme (UNDP). 1994. Human Development Report 1994.

United Nations Development Programme (UNDP). 2019. "Human Development Reports: Gender Inequality Index (GII)." Available at: http://hdr.undp.org/en/content/gender-inequality-index-gii [Accessed April 1, 2019].

United Nations. "Goal 5: Achieve gender equality and empower all women and girls." Available at: https://www.un.org/sustainabledevelopment/gender-equality/ [Accessed April 1, 2019].

United Nations. 2005. "The Millennium Development Goals Report." Available at: https://unstats.un.org/unsd/mi/pdf/MDG Book.pdf.

Unterhalter, E., A. North, M. Arnot, C. Lloyd, L. Moletsane, E. Murphy-Graham, J. Parkes, and M. Saito. 2014. "Girls' education and gender equality." Available at: http://r4d.dfid.gov.uk/.

Vargas Hill, R., and M. Vigneri. 2011. "Mainstreaming gender sensitivity in cash crop market supply chains." Available at: www.fao.org/economic/esa.

Veettil, P.C., B.K. Mohapatra, P.T. Raghu, and S. Mohanty. 2016. "Youth in Agriculture : Involvement and Career Preferences of Rural Youth across Rice Value Chain."

World Bank, Food Agriculture Organization (FAO), and International Fund for Agricultural Development (IFAD). 2009. "Gender in agriculture sourcebook."

World Bank. 2006. "Gender equality as smart economics: A World Bank Group Gender Action Plan (Fiscal years 2007–10)."

World Bank. 2007. "World Development Report 2008: Agriculture for Development."

World Bank. 2011. "Gender Equality and Development." Available at: https://siteresources.worldbank.org/INTWDR2012/Resources/7778105-1299699968583/7786210-1315936222006/Complete-Report.pdf.

World Bank. 2011. "Gender Equality and Development." Available at: https://siteresources.worldbank.org/INTWDR2012/Resources/7778105-1299699968583/7786210-1315936222006/Complete-Report.pdf.

World Bank. 2017. "Popuation Totals." Available at: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=IN-CN.

World Bank. 2018. "India States Briefs." Available at: http://www.worldbank.org/en/news/feature/2016/05/26/india-states-briefs.

World Bank. 2018. "India States Briefs." Available at: http://www.worldbank.org/en/news/feature/2016/05/26/india-states-briefs.

World Economic Forum. 2018. The Global Gender Gap Report. Available at: https://www.weforum.org/reports/the-global-gender-gap-report-2018 .

World Economic Forum. 2018. The Global Gender Gap Report. Available at: https://www.weforum.org/reports/the-global-gender-gap-report-2018 .

Yamano, T. 2015. "Rice Monitoring Survey: South Asia." Available at: http://ricestat.irri.org/fhsd/php/panel.php.

Yamano, T. 2015. "Rice Monitoring Survey: South Asia." Available at: http://ricestat.irri.org/fhsd/php/panel.php.

Yamano, T., P. Veetil, I. Gupta, J. Johny, D. Villanueva, P. Ricarte, and H. Valera. 2017. "Rice Monitoring Survey 2016 in India."

Yamano, T., P. Veetil, I. Gupta, J. Johny, D. Villanueva, P. Ricarte, and H. Valera. 2017. "Rice Monitoring Survey 2016 in India."

Zepeda, L., and M. Castillo. 2006. "The Role of Husbands and Wives in Farm Technology Choice." American Journal of Agricultural Economics 79(2):583.

## Appendix

## A. Index breakdown

### A.1 Index on agricultural household decision making:

The index was based off the calculation method of the Women's Empowerment in Agriculture Index (WEAI) by International Food Policy Research Institute (IFPRI).

The overall index was made up production, resources, income, and leadership. Where, if empowerment was reached in any of the areas – a women was considered empowered.

**i.** Production

a. Inputs in productive decisions – Part one:

   i. Did you participate in the [ACTIVITY] in the last 12 months?
      - Yes, No

   ii. How much input did you have in making decisions about [ACTIVITY]?
      - No, few, some, most, or all input, and N/A

   iii. How much input did you have in decisions on the use of income generated from [ACTIVITY]?
      - No, few, some, most, or all input, and N/A

Where [ACTIVITY] included: Food crop farming, cash crop farming, livestock raising, fishing/ fishpond culture

Empowerment was recorded as a 1 or 0 if the individual participated in the [ACTIVITY], and had some, most or, all input into decisions as a response in question 2 and 3.

b. Inputs in productive decisions – Part two:

   i. When decisions are made regarding the following [ACTIVITY] of household life, who is it that normally takes the decision?
      - Member

   ii. To what extent do you feel you can make your own personal decisions regarding these [ACTIVITY] of household life if you want(ed) to?
      - None, small, medium, or high extent

Where [ACTIVITY] included: Selection of crop, Selection of variety, use of production, crop planting/ sowing activities, wage and salary employment, and livestock raising.

Empowerment was recorded as a 1 or 0 if the individual participated in the [ACTIVITY], and had medium or high extend of participation in decision making as a response in question 2.

Overall adequacy / empowerment in production was determined by summing all [ACTIVITY] together. If an individuals sum was greater than 2, they were determined to be empowered.

**ii.** Resources

a. Ownership of assets – Part 1:

   i. Does anyone in your household currently have any [ITEM]?
      - Yes, No

   ii. Do you own any of the [ITEM]?
      - Yes (solely), Yes (jointly), No

Where [ITEM] included: Agricultural land (pieces/plots), Large livestock (oxen, cattle), Small livestock (goats, pigs, sheep), Poultry (Chickens, Ducks, Turkeys, Pigeons), Fish pond or fishing equipment, Farm equipment (non-mechanized: hand tools, animal-drawn plough), Farm equipment (mechanized: tractor-plough, power tiller, treadle pump), Nonfarm business equipment (solar panels used for recharging, sewing machine, brewing equipment, fryers), House or other structures, Large consumer durables (refrigerator, TV, sofa), Small consumer durables (radio, cookware), Cell phone, Other land not used for agricultural purposes (pieces/plots, residential or commercial land), Means of transportation (bicycle, motorcycle, car)

Empowerment was recorded as a 1or 0, if the individuals household owned some of the [ITEM] and they owned it jointly or solely. Overall empowerment in the ownership of assets was a sum of the [ITEM]'s – excluding poultry, non-mechanized, and small durable. If the total was above 1, the individual was marked as empowered in the ownership of assets.

b. Access to Credit – Part 2:

   i. Has anyone in your household taken any loans or borrowed cash/in-kind from [SOURCE] in the past 12 months?
      - Yes, No

   ii. Who made the decision to borrow from [SOURCE]? (main and second decision maker)
      - Member

Where [SOURCE] included: Non- governmental organization (NGO), informal (moneylenders, trader, informal credit group), formal (banks, self help groups), friend/relative, Group based micro finance (microfinance institution, cooperative/ society)

Empowerment was determined if the individual's household had received credit for any [SOURCE] and the individual was the main or second decision maker on the decision to get credit

Overall adequacy / empowerment in resources was determined if the individual was empowered in each part – meaning that the individual owned at least of the specified [ITEM]'s and was part of the households decision to get credit the any [SOURCE].

**iii.** Income

a. Control over use of income – Part 1:

   i. Did you participate in the [ACTIVITY] in the last 12 months?
      - Yes, No

   ii. How much input did you have in decisions on the use of income generated from [ACTIVITY]?
      - No, few, some, most, or all input, and N/A

Where [ACTIVITY] included: Food crop farming, cash crop farming, livestock raising, fishing/ fishpond culture, non-farm economic activities, wage and salary employment.

Empowerment was recorded as a 1 or 0 if the individual participated in the [ACTIVITY], and had some, most or, all input into decisions as a response in question 2.

b. Control over use of income – Part 2:
   i. When decisions are made regarding the following [ACTIVITY] of household life, who is it that normally takes the decision?
      - Member
   ii. To what extent do you feel you can make your own personal decisions regarding these [ACTIVITY] of household life if you want(ed) to?
      - None, small, medium, or high extent

Where [ACTIVITY] included: wage and salary employment, major household expenditures, minor household expenditures.

Empowerment was recorded as a 1 or 0 if the individual participated in any [ACTIVITY] – excluding minor household expenditures- , and had medium or high extend of participation in decision making as a response in question 2.

Overall adequacy / empowerment in income was determined by summing all [ACTIVITY] together. If an individuals sum was greater than 1, they were determined to be empowered.

**iv.** Leadership

a. Group Membership
   i. Are you a member of a group?
      - Yes, No

Overall adequacy / empowerment in leadership was determined if the individual was a member of a group. If they were, they were listed as empowered.

### A.2 Disaggregate indices

Decision made at the extensive margin

i. Production and productive outputs decision making
   a. Are they involved in the [ACITIVITY] decision?
      - Yes, No

Where [ACITIVITY] included: Selection of Crop, Selection of Variety, Crop planting/ sowing activities, Food crop farming, Cash crop farming, Livestock raising, Fishing/ fishpond cultivation

Overall adequacy if individual was involved in at least one [ACITIVITY].

ii. Marketable Surplus decision making
   a. Are they involved in the [ACITIVITY] decision?
      - Yes, No

Where [ACITIVITY] included: Use of production

Overall adequacy if individual was involved in the [ACITIVITY].

iii. Household labour decision making
   a. Are they involved in the [ACITIVITY] decision?
      - Yes, No

Where [ACITIVITY] included: household labour

Overall adequacy if individual was involved in the [ACITIVITY].

iv. Wage and salary employment decision making
   a. Are they involved in the [ACITIVITY] decision?
      - Yes, No

Where [ACITIVITY] included: Wage and salary employment

Overall adequacy if individual was involved in the [ACITIVITY].

v. Household Expenditure decision making
   a. Are they involved in the [ACITIVITY] decision?
      - Yes, No

Where [ACITIVITY] included: Major household expenditures, Minor household expenditures, Child’s Education.

Overall adequacy if individual was involved in at least one [ACITIVITY].

vi. Family planning decision making

a. Are they involved in the [ACITIVITY] decision?
   - Yes, No

Where [ACITIVITY] included: family decision

Overall adequacy if individual was involved in the [ACITIVITY].

vii. Land ownership

a. Does anyone in your household currently have any [ITEM]?
   - Yes, No
b. Do you own any of the [ITEM]?
   - Yes (solely), Yes (jointly), No

Where [ITEM] included: Agricultural land, House and Other Structures, and Other land.

Overall adequacy if individual was owned at least one [ITEM] either joint or solely.

viii. Credit Access

a. Has anyone in your household taken any loans or borrowed cash/in-kind from [SOURCE] in the past 12 months?
   - Yes, No
b. Who made the decision to borrow from [SOURCE]? (main and second decision maker)
   - Member

Where [SOURCE] included: Non- governmental organization (NGO), informal (moneylenders, trader, informal credit group), formal (banks, self help groups), friend/relative, Group based micro finance (microfinance institution, cooperative/ society)

Empowerment was determined if the individual's household had received credit for any [SOURCE] and the individual was the main or second decision maker on the decision to get credit

Sub - index on productive (explicitly) decision making: made as a sum of production and productive output, marketable surplus, and household labour decision making. Where empowerment is determined if the sum of the three components is at least 1.

## B. Bandwidth calculations

Optimal bandwidths were determined by conducting a grid search of bandwidth options. This method was selected based on sample size and previous literature. Bandwidths shown in the below calculation include 500, 400, 300, 200, and 100. Villages included in the sample were unconnected as of the 2001 National Population Census.

The simple model of equation 3 was run for the outcomes of *overall women's power* (1), *aggregate agriculture* (aggregate of all production based decision making) (2), *aggregate off farm* (aggregate of all consumption and off-farm labour based decision making) (3), *land ownership* (4), and *access to credit* (5), respectively shown in column 1 to 5 of each table. The final selection was determined by comparing significance across models. The final determination resulted in a bandwidth of 200 being selected as optimal for the analysis.

**Table B1**: Results for baseline 2SLS model depicting the fuzzy RD for specified outcomes using a bandwidth of 500, Eastern India, 2016

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | *Overall women's power* | *Aggregate agriculture* | *Aggregate off farm* | *Land ownership* | *Access to credit* |
| Connection Status | -92.516** | -30.726*** | 6.531 | 22.833*** | -6.418 |
| | (41.259) | (6.712) | (7.132) | (6.006) | (7.422) |
| Normalized Population | 0.015** | 0.000 | -0.002 | -0.002 | 0.002 |
| | (0.006) | (0.001) | (0.001) | (0.001) | (0.001) |
| Constant | 210.726*** | 27.579*** | 23.868*** | 9.336*** | 30.478*** |
| | (9.027) | (1.728) | (1.836) | (1.546) | (1.911) |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Table B2**: Results for baseline 2SLS model depicting the fuzzy RD for specified outcomes using a bandwidth of 400, Eastern India, 2016

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | *Overall women's power* | *Aggregate agriculture* | *Aggregate off farm* | *Land ownership* | *Access to credit* |
| Connection Status | -116.420** | -34.898*** | 11.449 | 13.296* | -35.510*** |
| | (47.564) | (9.322) | (9.868) | (8.012) | (10.873) |
| Normalized Population | 0.020*** | 0.000 | -0.003* | 0.002 | 0.008*** |
| | (0.007) | (0.002) | (0.002) | (0.001) | (0.002) |
| Constant | 216.259*** | 27.949*** | 22.746*** | 11.895*** | 36.740*** |
| | (9.502) | (2.240) | (2.371) | (1.925) | (2.612) |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Table B3**: Results for baseline 2SLS model depicting the fuzzy RD for specified outcomes using a bandwidth of 300*,* Eastern India, 2016

| | (1) *Overall women's power* | (2) *Aggregate agriculture* | (3) *Aggregate off farm* | (4) *Land ownership* | (5) *Access to credit* |
|---|---|---|---|---|---|
| Connection Status | -127.223*** | -22.287*** | 5.431 | 11.552** | -9.637 |
| | (32.591) | (5.372) | (5.783) | (4.752) | (6.038) |
| Normalized Population | 0.027*** | -0.004** | -0.001 | 0.003* | -0.005*** |
| | (0.008) | (0.002) | (0.002) | (0.001) | (0.002) |
| Constant | 219.369*** | 25.325*** | 24.142*** | 12.376*** | 30.497*** |
| | (6.597) | (1.321) | (1.422) | (1.169) | (1.485) |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Table B4**: Results for baseline 2SLS model depicting the fuzzy RD for specified outcomes using a bandwidth of 200*,* Eastern India, 2016

| | (1) *Overall women's power* | (2) *Aggregate agriculture* | (3) *Aggregate off farm* | (4) *Land ownership* | (5) *Access to credit* |
|---|---|---|---|---|---|
| Connection Status | -350.494*** | -26.707*** | 19.121* | 20.016** | 38.047*** |
| | (87.453) | (9.576) | (10.450) | (8.603) | (10.912) |
| Normalized Population | 0.188*** | -0.002 | -0.012** | -0.007 | -0.039*** |
| | (0.040) | (0.005) | (0.006) | (0.005) | (0.006) |
| Constant | 276.294*** | 27.314*** | 19.892*** | 9.547*** | 19.208*** |
| | (20.749) | (2.765) | (3.017) | (2.484) | (3.150) |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Table B5**: Results for baseline 2SLS model depicting the fuzzy RD for specified outcomes using a bandwidth of 100, Eastern India, 2016

| | (1) *Overall women's power* | (2) *Aggregate agriculture* | (3) *Aggregate off farm* | (4) *Land ownership* | (5) *Access to credit* |
|---|---|---|---|---|---|
| Connection Status | 944.655 | -452.150 | 620.978 | 70.410 | 857.919 |
| | (1,595.670) | (1,201.634) | (1,689.092) | (279.507) | (2,265.306) |
| Normalized Population | -1.324 | 0.682 | -0.962 | -0.094 | -1.337 |
| | (2.169) | (1.873) | (2.633) | (0.436) | (3.531) |
| Constant | -10.782 | 152.124 | -158.145 | -6.768 | -221.762 |
| | (356.469) | (353.898) | (497.461) | (82.319) | (667.164) |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1