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The impact of credit policy on rice production in Myanmar: A fuzzy regression discontinuity design approach

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Abstract

Rural finance has long been an important tool for poverty reduction and rural development by donors and governments, but the impacts have been controversial. Measuring impact is challenging due to identification problems caused by selection bias and governments' targeted interventions, while randomised trial data is scarce and limited to contexts where little to no rural finance exists. Using an author-collected data set, we provide insights on a large-scale long-lasting subsidized rice credit programme in Myanmar, one of the poorest and, until recently, most economically isolated countries in Asia. Identification relies on a fuzzy regression discontinuity design, exploiting an arbitrary element to the credit provision rule which is based on rice land holding size. Although we find little evidence that rice yield or output is increased, we do see that the program has some positive effects on total household income, suggesting a positive spillover effect on other farm income activities.

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1. Introduction

Over the last six decades, Myanmar has relied on government subsidized credit for household farms as a key financing policy to improve agricultural productivity. The ultimate goal of this policy, as in many developing countries, is to reduce poverty and develop rural areas. At the global level, the last six decades can be divided broadly into two distinct episodes of growth and transformation in rural finance. The first episode, from the 1950s to the mid-1980s, witnessed large-scale credit programs, subsidised by governments and donors, being channelled to the agricultural sector with an aim to increase rural incomes.[1] Contrary to expectations, most of these programs performed badly with high default rates (Adams et al., 1984), repressed financial markets (McKinnon, 1973), and outcomes that benefited the rich more than the poor (Gonzalez-Vega, 1984). The second episode is rooted in the early 1990s and characterized by group lending, a so-called 'critical innovation'. Funding comes mainly from non-governmental organizations (NGOs) to providing loans to poor people lacking any financial security (Armendáriz and Morduch, 2010). Early successful experience has brought about an exponential growth of microcredit clients (Morduch, 1999). By 2006, a Nobel Peace Prize was awarded to the pioneers in group lending. However, this momentum came to a halt due to the microfinance crisis in India in 2010. In fact, this microfinance crisis, which is the largest to date, has raised serious concerns about the impact and sustainability of microfinance (Mader, 2013) generally.

Measuring the impact of credit programs is challenging due to a self-selection bias. This challenge is further complicated by the targeting nature of financial institutions' and governments' policies. From a methodological point of view, the preferred approach to address these identification problems is to use a randomized control trial (RCT). Thus far, most of the handful of published field experiments consistently show that credit yields a modestly positive, but not transformative effect on household income and expenditure (Banerjee et al.,

[1] For example, the injection of credit into the rural sector in Brazil increased from US$ 2 billion in 1970 to US$ 20.5 billion in 1979 (Kaboski and Townsend, 2011); the annual World Bank lending for agricultural credit project was over US$ one billion in the 1980s (Conning and Udry, 2007).

2015). An alternative approach to measure the impact of credit programs is to use natural experiments. For example, Kaboski and Townsend (2012) used the one-off lump-sum funding for each village regardless of its size provided by the government of Thailand as a natural experiment. They showed that this liquidity injection has boosted households' consumption and income but slowed down their asset growth.

Despite their advantages in measuring an impact, RCTs are resource-intensive and politically infeasible while natural experiments are not readily available. Moreover, experiments tend to measure the impact of credit on *marginal*, not *infra*-marginal borrowers (Banerjee et al., 2015). The underlying reason is that RCTs are typically implemented in contexts where little or no rural finance exists to avoid possible confounding factors, thus revealing the impact only on marginal borrowers. While this knowledge is highly policy relevant, it is also important to learn about the impact on *infra*-marginal borrowers to justify existing lending programs. Finally, credit lending modalities are diverse, and their impact can be highly contextual, calling for more rigorous evidence from various settings.

In this light, we aim to make two contributions to the literature. First, we use a fuzzy regression discontinuity (FRD) approach to measure the impact of a large-scale long-lasting subsidized credit programme for rice production in Myanmar. Identification relies on an arbitrary element in the credit provision rule, which sets a threshold of 10 acres as the maximum for farmers to borrow a fixed amount per acre of rice land holding. As this credit programme has been implemented for decades, our estimates reflect the impact on infra-marginal borrowers.[2] The second contribution is the unique case study of Myanmar that this paper offers. Using author-collected data, we shed light on a country which has come out of its self-imposed isolation from the world only recently and seriously lacks reliable micro data and statistics for farm households. In Myanmar's apparently underdeveloped financial sector, however, the government subsidized credit program has much higher repayment

[2]The use of a FRD design to assess the effects of micro credit is not new. For example, Aktaruzzaman and Farooq (2016) use data from 69 villages in Bangladesh to estimate the impact of credit on household expenditure. Also relying on a discontinuity around land size, they found a positive impact of credit on spending at the village level, but mixed effects on the household level. Due to different contexts, data, and the lack of external validity regarding FRD, these findings are not directly comparable to ours.

rates compared to similar programmes in other countries. One of the underlying reasons is arguably the group lending being implemented as early as in 1965/1966, well ahead of the global renovation in microfinance in the 1990s.

Using a sample of 628 farms in three key rice producing regions, we find little evidence that rice yield or output is increased as targeted. However, the program does increase total household income, suggesting positive spillover effects on other farm income activities.

2. Brief History of Institutional Rural Credit in Myanmar

Until recently, Myanmar had been isolated from the world for decades due to its inward-looking self-reliant policy in the form of "Burmese Way of Socialism." As a result, it remains an agricultural economy in which the agricultural sector represents between 35 to 40 percent of gross domestic product (GDP), up to 70 percent of the labour force and generates between 25 to 30 percent of total export earnings (De Luna-Martinez and Anantavrasilpa, 2014). Rice dominates the agricultural sector, being the main staple of the national diet and a primary source of income for both household and country. In this context, stimulating rice production has been a key priority for the Myanmar government (MoAI et al., 2015), defining its rural finance policies. This section discusses the history of rural institutional finance since the independence in 1948 until recently.

2.1. From the independence to the first reform in 1987/1988

Despite the emphasis on providing sufficient institutionalized agricultural credit to support the agricultural sector, the government had met only 12–15 percent of the need for rural credit by 1953 (Steinberg, 1981). Since loans, which were provided at 6.5 percent interest rate per year, were not secured and supervised, their repayment was poor, leading to outstanding farm debt being more than half of farm income (Steinberg, 1981).

The State Agricultural Bank (SAB) was established in 1953 as Myanmar's fundamental institution for rural finance. Yet for the first five years, credit was channeled to farmers via trained field workers and through cooperatives. Eventually, a network of village banks was gradually developed, from 1290 banks in 1958 to 11,207 banks in 1978, with a presence in almost every village in the country (Steinberg, 1981). From 1953 to 1960, agricultural loans provided by the SAB satisfied just under a quarter of total demand. Interest rates charged to farmers were 12 percent per year in late 1950s (Win, 1991) while reported repayment rates vary by source, ranging from 70-80 percent to 92 percent (World Bank, 1974; Win, 1991).

From 1964 onward, the SAB introduced measures to increase loan repayments. In particular, it reduced the total amount of new loans and provided these only to farmers who had repaid their previous loans (World Bank, 1974). Besides, it imposed a penalty charge of 1% per month above the regular interest charge to borrowers with overdue loans. Finally, from 1965 to 1971, members of village banks were held collectively responsible for repayment of loans. These measures initially improved loan repayments, up to 96 percent in 1969, but then deteriorated again in the early 1970s (World Bank, 1974, p36). During this period the SAB charged an interest rate of 9 percent, of which village banks kept 6 percent for their operation and bore the burden of unpaid debts. In 1970, the SAB merged (as the Agricultural Finance Division) with the People's Bank, to form the Union of Burma Bank (UBB), the only bank in Myanmar under a mono-bank system.

Although the high repayment rates in the late 1960s were commendable given that the loans were unsecured, there were some issues with government credit provision. First, loans that became delinquent were usually not followed up and repaid in later years, which resulted in a growing number of farmers ineligible to receive new loans (World Bank, 1974). Second, a severe shortage of institutional credit led to a predominant role of illegal private credit. With interest rates ranging from 40 to 400 percent per year, private credit was estimated to be three times as much as institutional credit (Steinberg, 1981). Finally, farmers used up to 35 percent of crop production credit for their subsistence expenses before harvest, a further amount spent on hired labour, and only a small share of credit spared for seed, fertilisers and other productive inputs (World Bank, 1974).

Between 1973 and 1977, the lending operations of village banks reduced substantially due to the implementation of an advance purchase system by the cooperative societies. Under this system, farmers could receive an advance of up to 70 percent of the government procurement quotas in cash and kind (Steinberg, 1981). In June 1974, the government initiated another advance purchase system but only in rice surplus areas in Lower Burma, while other areas continued to be serviced by village banks (Steinberg, 1981). In these rice surplus areas, farmers could get a further advance from the government, contingent upon their land holding area, but were required to sell their corresponding produce to the state at the state price. Although the official interest was zero under this system, the effective interest could be substantial due to the wedge between the state price and the market price, resulting in farmers' reluctance to participate. Private lending, though illegal, was estimated to account for about 40 percent of total rural credit provided at interest rates of up to 10 percent per month (Steinberg, 1981).

In 1976, the Agricultural Finance Division was separated from the UBB to become the Myanmar Agricultural Bank (MAB). The separation followed the 1975 Bank Law, under which the mono-bank system was dismantled; the UBB became the central bank, and three specialized banks emerged under its supervision. In addition to the MAB, these included the Myanmar Economic Bank (MEB) and the Myanmar Foreign Trade Bank. The MAB was in charge of providing seasonal, medium-term, and long-term agricultural loans.

From 1978 to the early 1980s, the MAB had increased its disbursement substantially to support the launch of the Whole Township Rice Production Programme (WTRPP) in 1978. This WTRPP introduced modern high yielding varieties (HYV) of rice to enhance production possibilities. As a result, the MAB's lending increased due to both the expansion of area devoted to HYV and the rise in lending rates to satisfy a much higher need for fertilizer of HYV to generate high yields. Farmers received loans via village banks at the interest rate of 12 percent and were required to save 1 percent of the loan. Village banks enjoyed a margin of 4 percent interest rate, a 10 percent commission on the loan principal recovered plus 2 percent of all interest recovered (Win, 1991). These incentives, as well as increased supervision, contributed to smooth disbursement and recovery rates over 90 percent for seasonal loans. At the same time, the MAB's lending portfolio skewed heavily in favor of rice production, covering 85-88 percent of all crop loans and approximately 80 percent of the credit requirement for rice (Win, 1991).

But as the economy deteriorated in the mid-1980s, farmers again faced severe credit constraints. With inflation around 20 to 30 percent per annum, money printing to finance budget deficits, the demonetization of currency notes in 1985 and 1987 and the removal of subsidies on agricultural inputs such as fertilizer in 1987, agricultural inputs became less affordable for farmers. As a result, fertilizer usage dropped to levels as low as before the launch of the WTRPP, reducing the effectiveness of the WTRPP in expanding the use of HYV.

2.2. From the first reform 1987/1988 to present

A market-oriented policy was adopted in 1988, followed by the promulgation of new bank laws to open the financial sector to private and foreign investors. This policy change also saw a restructuring of the MAB. First, the nation-wide network of about 11,200 village banks was replaced with a system of branch banks between 1998 and 2000 (Fujita et al., 2009). This branch network has 220 banks as of 2013, accounting for 23 percent of all bank branches in Myanmar (De Luna-Martinez and Anantavrasilpa, 2014). Second, the MAB was transferred to the Ministry of Agriculture and Irrigation (MoAI) from the Ministry of Finance and Revenue and subsequently renamed as the Myanmar Agricultural Development Bank (MADB) in 1996. However, the reforms in the financial sector that were initially planned in 1988 were implemented only partially due to the Asian crisis in 1997 and the banking crisis in early 2003.

Since 2010, disbursement of seasonal loans by the MADB has apparently increased sharply, with the amount disbursed for 2012-2013 being 46 fold of that in 2000-2001 (Win, 2013). Nonetheless, this increase was mainly due to the rise in sown areas, not the number of borrowers; and the growth in disbursement was lower than the average annual inflation rate of over 20 percent from 2000 to 2009. Since 2013, the MADB has become dependent on government subsidies, due to a sharp decline in interest margins, causing a fiscal burden of about 0.2 percent of GDP (De Luna-Martinez and Anantavrasilpa, 2014).

Due to this funding shortage, the MADB has narrowed its lending portfolio to a limited number of crops. This narrowed portfolio is implemented despite MADB's mission of providing banking services to support the development of agriculture, livestock, and rural socio-economic enterprises. In general, the MADB offers two types of loans including seasonal crop production loans (SCPL) and term loans (TL), which, in 2002 for example, accounted for 98 percent and 2 percent of the total loans in 2012, respectively (De Luna-Martinez and Anantavrasilpa, 2014). Since 1998, SCPL loans have been provided to the production of eight main crops: paddy, groundnut, pulses, sesame, cotton, jute, maize and mustard (Win, 2013). The maximum loan size is based on the agricultural land holding area and capped at 10 acres per farm household (personal communication with an MADB manager). The TL loans are to finance sugarcane plantation, tea processing and solar salt production. Monsoon season loans dominate the MADB loan portfolio, accounting for 85 percent of which 88 percent are for paddy (De Luna-Martinez and Anantavrasilpa, 2014). Nevertheless, the MADB loans still cover only 25 to 50 percent of paddy farmers' production costs (Haggblade et al., 2013).

Unlike agricultural banks in other developing countries, the MADB has maintained high repayment rates despite lending without collateral. For example, its non-performing loans represented only 0.02 percent of the total lending in 2012-2013 (Win, 2013). This record is attributed to a few reasons. First, group lending was implemented as early as 1965/1966 and has been fully implemented since 1998, which requires farmers to form lending groups of 5 to 10 members, accepting liability for both their individual and other group members' loans (World Bank, 1974; Fujita et al., 2009). Furthermore, the MADB only provides loans to farmers in townships with full repayment history. Second, in addition to having a good credit history, farmers need land titling rights to be eligible for MADB loans. These rights were required for annual registration and renewal until 2012. Under the new land laws, farmers have more freedom to sell, transfer, mortgage or rent their land use rights to others. Due to the widespread lack of land titles, more than 3.5 million farmers are not served by the MADB (De Luna-Martinez and Anantavrasilpa, 2014). Finally, farmers need to have their loan applications approved by a village loan screening committee which comprises of the head of village and representatives from the Land Record Department, the Department of Agriculture, the Industrial Crop Department, and the farmers, thereby reducing information asymmetry problems (De Luna-Martinez and Anantavrasilpa, 2014).

Since the adoption of the Microfinance Law in 2011, the rural credit sector in Myanmar has been diversified. Based on limited data, an estimate by Duflos et al. (2013) suggests that the outstanding loans of MADB represented only 36 percent of the total outstanding loans by all microfinance providers in 2011-2012, but its clients accounted for more than half of total clients served by these institutions. The latter is due to the MADB having the largest bank network covering the whole country.

3. Study Areas, Data Collection, Crop Credit Market and Variables

3.1. Study Areas and Data Collection

Our empirical analysis draws on a farm household survey conducted in 2014. The sample of farm households was selected using a stratified multistage sampling procedure. The survey was canvassed in Myanmar's three main rice producing regions, Ayeyarwady, Bago and Sagaing, which accounted for roughly 26 percent, 17 percent and 12 percent, respectively, of the total rice output in Myanmar in 2012-2013 (MoAI, 2013). In each region, the district with the highest rice output was selected as strata in our sampling frame.[3] Two townships from each district were then randomly sampled, and five villages from each township. In the final stage of sampling, farm households were randomly drawn using a circular systematic sampling method with probabilities of being selected proportional to the village's number of farm households. We interviewed 634 farms households in total, of which 215 were in Ayeyarwady, 212 in Bago and 207 in Sagaing. Out of of 634 interviewed households, 628 are eligible for MABD credit and used in this paper.

The regions vary greatly in soil type, irrigation and remoteness, which is subsequently reflected in household rice production, crop diversity and income sources. For example, the soil in the two Ayeyarwady townships is gley or gley swampy, while Bago features meadow

[3]The districts Pyapon in Ayeyarwady, Bago in Bago and Shwebo in Sagaing.

and alluvial meadow. In contrast, the soil in the Sagaing townships varies from meadow and alluvial meadow to red-brown forest soil. The Ayeyarwady and Bago regions are located in the Delta Region where monsoon paddy is usually rain-fed, whereas Sagaing is located in the Central Dry Zone and rice production typically relies on irrigation. Finally, Ayeyarwady and Bago are located near Yangon, the largest city and former capital of Myanmar, while Sagaing is more remote, bordering India in the north of Myanmar.

3.2. Crop Credit Market

Table 1 provides detailed information on crop credit received by farms in the sample. On average, the outstanding loans in our sample run for about six months, which suggests that these are likely seasonal crop production loans. Loans for rice production dominate in all regions, and especially in Ayeyarwady where they account for 100 percent of all crop credit. The MADB plays a dominant role in loan supply, providing 81 percent of loans in Sagaing, 58 percent in Bago and 64 percent in Ayeyarwady, mostly for rice production. Farmers reported having to satisfy all MADB loan requirements: having land-use-right certificates, having a savings account at MADB, and being part of a lending group in addition to being approved by a village loan screening committee. They were charged an interest rate of 0.71 percent per month (or 8.5 percent per annum) and could borrow for up to 10 acres only. All but one (due to illness) repaid both principal and interest when loans reached maturity. The second primary source of credit is from relatives, accounting for 4-5 percent, 17-18 percent and 12 percent in Sagaing, Bago and Ayeyarwady, respectively, of household total credit amount. Interest rates per month are much higher than those set by the MADB, at about 4 percent in Sagaing, 5 percent in Bago and almost 8 percent in Ayeyarwady. NGOs and other credit institutions such as pawn shops play a negligible role in credit supply for crop cultivation in the three study regions.[4]

[4]Our data shows a slightly different picture of the credit market compared to LIFT (2012) regarding the source of credit and interest rates. In particular, LIFT (2012) find that the key source of credit for households is families, friends and brokers and the interest rates are 10-20 percent per month. This difference comes from different samples, with LIFT (2012) covering all households who live in a broader geographical area, while our sample includes only rice farm households from three regions.

Table 1: Crop Credit Market

Region	Item	Non Rice Crops					Rice				
		Relatives	Brokers	MADB	NGO	Others	Relatives	Brokers	MADB	NGO	Others
Sagaing	Interest rate (%/month)	2.5		0.7			4.3	0.8	0.7	1.5	1.5
		[3.5]		[0.0]			[3.0]	[2.0]	[0.0]	[.]	[1.3]
	Duration (months)	6.0		6.4			6.2	5.8	6.4	6.0	5.3
		[1.4]		[0.5]			[1.3]	[1.2]	[0.5]	[.]	[2.0]
	Amount (USD)	550		198			527	417	586	100	241
		[212]		[369]			[424]	[306]	[276]	[.]	[406]
	% of credit amount	5		95			4	1	91	1	4
		[19]		[19]			[12]	[7]	[18]	[.]	[12]
	Observations	2		28			15	6	164	1	21
Bago	Interest rate (%/month)	5.4	6.0	0.7		4.9	5.2	5.5	0.7	2.8	2.3
		[2.2]	[0.0]	[0.0]		[1.7]	[2.1]	[4.0]	[0.0]	[1.1]	[1.9]
	Duration (months)	6.1	7.0	6.1		6.8	6.3	7.2	6.4	5.8	5.8
		[1.6]	[0.0]	[0.6]		[2.5]	[1.8]	[2.9]	[0.5]	[0.6]	[1.8]
	Amount (USD)	794	925	194		1475	1055	1150	967	447	652
		[649]	[435]	[175]		[1284]	[1036]	[859]	[594]	[1020]	[1062]
	% of credit amount	17	8	68		8	18	6	70	1	6
		[35]	[24]	[42]		[25]	[24]	[17]	[26]	[4]	[15]
	Observations	8	4	40		4	91	22	220	11	48
Ayeyar-	Interest rate (%/month)						7.75	5.91	0.71	1.85	4.81
-wady							[14.0]	[1.7]	[0.0]	[1.1]	[14.4]
	Duration (months)						5.6	7.9	6.0	5.3	4.5
							[1.2]	[2.6]	[0.8]	[0.7]	[2.9]
	Amount (USD)						639	1068	724	253	1110
							[714]	[907]	[327]	[104]	[1333]
	% of credit amount						12	2	76	3	7
							[20]	[10]	[23]	[7]	[18]
	Observations						94	11	345	39	47

Notes: Standard deviations are in bracket.

3.3. Variables

The primary outcome variables for our analysis are related to rice production. Rice output is the total output of rice in kilogrammes for each farm over the full year 2013. Total income converted into USD is based on cash income from rice, other crops, livestock, fishery, horticulture and non-farm household business activities per year, all of which are recorded separately.[5] Farm spending on factor inputs, such as fertilizer, other material inputs and hired labour are also measured in USD. The key exploratory variable of interest is total MADB credit for summer paddy and monsoon paddy. For land size, we have information on the farm area with land use certificates, as well as the total sown land (both owned and rented, measured in acres) used in annual paddy production.

In addition to these key variables, we use a number of independent variables as controls in the regression analysis, as they may affect rice production. The demographic characteristics of a household are captured by the number of household members and the dependency ratio (the number of non-working family members over the total family size). The number of family members available to work determines both farm production and other sources of income. Proxies for the skill level of the farmers are the years farming experience and the education level of the household head. Education is categorized by three different levels: at most primary school, secondary school, and high school or higher education. We also include the age and gender of the household head. The respondent farmers were asked to self-assess the water availability from irrigation or natural sources, such as creeks, rivers, dams and reservoirs, and private channels (rating as 1=poor, 2=average, 3=good or 4=very good). Availability of agricultural extension services is defined as a farm household receiving services for farming activities, be it from the government, private agencies or NGOs. The distance from a village to a township is considered to be an important factor in applying for agricultural credit. Due to a lack of good roads and transportation, travel time and transportation costs can pose substantial obstacles to credit and diminish production efficiency (Tracey-White, 2005). Li et al. (2011) show that households located close to township bank

[5]The prevalent exchange rate at the time of the survey was 1000 Kyat = 1 USD.

branches are more likely to apply for loans compared to those further away. In our sample, we see that households located approximately 96 kilometres from a township's branch bank do not apply for agricultural loans.

Table 2 shows the summary of descriptive statistics for the sample of farm households. The average farm in the sample cultivates 13.7 acres and produces about 15800 kg rice. Rice output is strongly correlated with land size, as expected. Farms with no more than 10 acres produce, on average, less than a quarter of what larger farms produce.

We see marked differences between the three regions. The delta regions, Ayeyarwady and Bago, enjoy conditions that are more favourable for farming, such as higher annual rainfall and fertile soils. Here, especially in Ayeyarwady, most farms plant two seasons of rice per year. Average planted land is therefore much larger in Ayeyarwady (19.7 acres) and Bago (14.6 acres) than in Sagaing (6.7 acres), as is rice production per farm in these regions (on average more than three times larger than in Sagaing). Almost all farms in the Delta region report to have good or very good irrigation, compared to just over half the respondents in Sagaing. The lack of sufficient availability of irrigated water in the dry zone reduces the incentive for farmers to cultivate rice and turn instead to other crops, such as pulses, sugarcane and peanuts which require less water but do enjoy increased export demand. These differences are reflected in rice income, which is roughly twice as high in the delta region. Within the delta region, we also see variation in farming practices. While rice production and income are by far higher in Ayeyarwady, total income is higher in Bago, as farms in Bago have a larger income share from other sources. Bago farmers are also relatively better educated and located much closer to markets.

Table 2: Summary Statistics

VARIABLES	Full sample mean	Full sample St. dev.	$\leq$10 acres mean	$\geq$10 acres mean	Sagaing mean	Bago mean	Ayeyar-wady mean	H_0: $\bar{X}_{\leq 10}$=$\bar{X}_{>10}$ P-value
Rice output (kg)	15,807	[16,960]	8,084	30,333	5,854	19,034	22,361	0.000
Rice yield (kg/acre)	1,086	[420]	1,053	1,148	800	1,290	1,163	0.007
Rice income (USD)	3,295	[3,651]	1,665	6,362	1,879	3,444	4,537	0.000
Total income (USD)	4,453	[4,598]	2,578	7,979	3,051	5,429	4,857	0.000
Fertilizer per planted acre (USD)	18.1	[23.5]	17.9	18.4	26.3	3.7	24.4	0.031
Rice inputs excl. fertilizer per planted acre (USD)	2.4	[5.7]	2.9	1.7	4.5	0.84	1.7	0.035
Hired labour (USD)	519	[720]	212	1,096	223	563	766	0.000
Family labour (USD)	147	[177]	122	194	117	159	165	0.000
Credit per acre (USD)	76.8	[39.7]	86.6	58.3	80.3	77.5	72.7	0.000
Rice land area with land use certificate (acre)	11.6	[11.3]	5.9	22.4	6.7	13.7	14.3	0.000
Rice planted area (owned or rented, acre)	13.7	[13.0]	7.2	25.9	6.7	14.6	19.7	0.000
Household head								
Age	51	[12]	51	52	52	52	49	0.246
Gender (1=male)	0.96	[0.21]	0.96	0.95	0.97	0.98	0.91	0.910
At most primary education (1=yes)	0.61	[0.49]	0.64	0.56	0.63	0.51	0.69	0.067
Secondary education (1=yes)	0.25	[0.44]	0.25	0.27	0.23	0.32	0.22	0.507
High school/higher education (1=yes)	0.13	[0.34]	0.11	0.17	0.14	0.17	0.09	0.075
Farming experience (years)	28	[13]	28	29	29	30	25	0.125
Number of household members	5.4	[1.9]	5.2	5.7	5.4	5.4	5.3	0.001
Dependency ratio	0.45	[0.23]	0.43	0.48	0.40	0.42	0.52	0.014
Irrigation deemed good/very good (1=yes)	0.82	[0.38]	0.78	0.90	0.55	0.94	0.97	0.000
Agricultural extension services (1=yes)	0.58	[0.49]	0.58	0.58	0.58	0.51	0.64	0.905
Distance to market (km)	17.0	[19.7]	18.6	14.0	28.2	6.5	16.6	0.006
Sagaing (Dry Zone) (1=yes)	0.33	[0.47]	0.43	0.15				0.000
Bago (Delta Region) (1=yes)	0.33	[0.47]	0.28	0.44				0.000
Ayeyarwady (Delta Region) (1=yes)	0.34	[0.47]	0.30	0.41				0.005
Observations	628		410	218	207	210	211	

4. Methods

The main objective of our empirical strategy is to identify the causal effect of the MADB credit scheme on rice production and income of farm households. The main threat of endogeneity comes from potentially confounding characteristics that affect both rice production and the amount of credit received. First, the targeting design favours relatively more able farmers that tend to have good credit histories. Second, the scheme involves an element of self-selection by which risk averse, lower educated, or less motivated or confident farmers are less likely to take up credit. Both these effects can lead to a positive bias, and hence an overestimate, of the effects of providing MADB credit on rice yields and income.

To address this problem, our identification strategy exploits the targeting design of the MADB program. This program introduces a discontinuity in eligibility around a threshold of 10-acre rice land area with right use certificates. Farms just below and just above this threshold are not equally eligible for a loan. Obviously, small and large farms are not a proper comparison, as land size is a key factor for production and income. Yet, if we look at a range close enough to the threshold, then there is no reason to expect that these farms are different in any characteristics other than the MADB eligibility. Note that this threshold is not a clear cut off for being eligible for a loan. Rather, it is the point at which the maximum amount of credit is reached. Farms having less than 10 acres of rice land with use right certificates are eligible to borrow USD 100 per acre per cropping season, and the maximum amount that can be borrowed increases linearly with the land size. For farms larger than 10 acres the total amount is capped at USD 1,000 per season for their first 10 acres, which means the average credit per acre decreases with land size. This setup, therefore, implies a fuzzy regression discontinuity design: farms on either side of the threshold receive credit, but at the threshold, there is a discontinuity in the eligible amount of credit per acre.

The discontinuity is clearly observed in Figure 1a, which plots the average amount of MADB credit received per acre per cropping season on the vertical axis, and the rice land size in acres on the horizontal axis.[6] For farms smaller than 10 acres the average amount of

[6] Both variables are based on land with certificates of use right.

credit per acre hovers around USD 100. The figure also suggests that some farms received more than the maximum eligible amount, especially among the very small farms. This apparent suggestion does not necessarily point to manipulation of targeting. Rather, these farms, most of them were in the dry zone Sagaing, were eligible for MADB credit for two seasons of rice; however, when crop time came, they were not able to cultivate rice in both seasons due to water availability.[7] Above 10 acres, we see an apparent decrease of MADB credit per acre, from about USD 80 at the discontinuity to below USD 20 per acre at 70 acres land size.

For the outcome variables, we observe a similar albeit less pronounced pattern around the 10-acre discontinuity. Figure 1b shows that total rice output is practically linear in land size, but we do see a small discontinuity around 10 acres. Regarding output per planted acre or rice yield, Figure 1c suggests clear economies of scale for small farms as land productivity increases up to around 20 acres when rice yield stabilizes at 1,100-1,200 kg/acre. But similar to the total output, we see a discontinuity at 10 acres.

The observed discontinuities reflect reduced form effects of the eligibility threshold on the amount of subsidized credit and rice production. To formally test the causal effects of the MADB scheme we estimate treatment effects with a simple instrumental variable setup

$$T_i = \pi_0 + \pi_1 D_i + \pi_l f(L_i) + \pi_x X_i + \epsilon_i \tag{1}$$

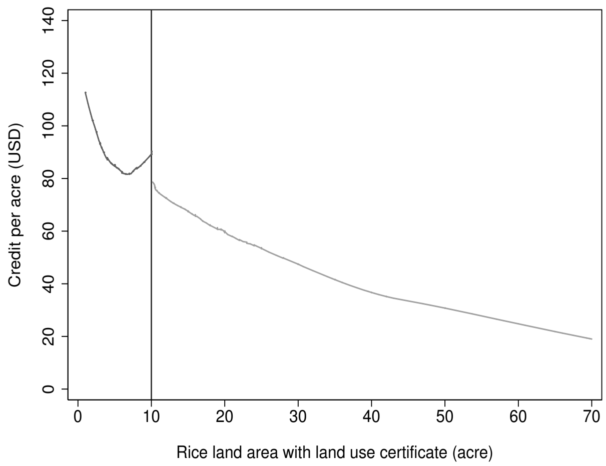
$$Y_i = \beta_0 + \beta T_i + \beta_l f(L_i) + \beta_x X_i + \nu_i \tag{2}$$

where an indicator variable for exceeding the 10-acre threshold (D_i) is used as an instrument for the average MADB credit per acre (T_i). We control for land size by including a third order land size polynomial (L_i), to capture the relationship between land size and the outcomes. Since the 10-acre threshold is an arbitrary decision, we expect that conditional on actual land size it does not affect rice production other than through the MADB scheme, satisfying

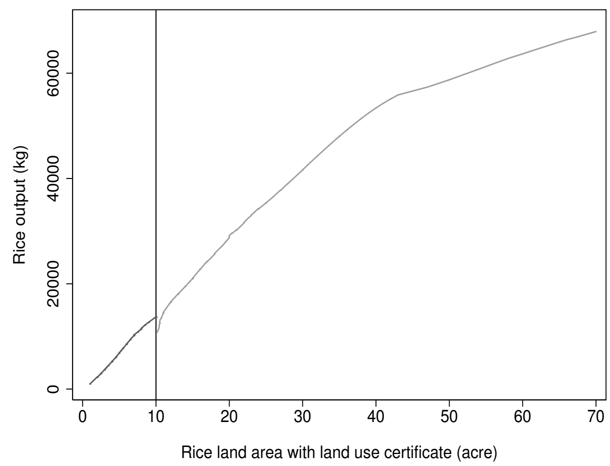
[7] Since most of the farms are relatively small, we also assess the sensitivity of the results to dropping the smallest farmers. As the results in the subsequent section will show, our results are robust to leaving out farms with titled rice land holdings smaller than 5 acres.

Figure 1: Discontinuities in credit, output and output per acre

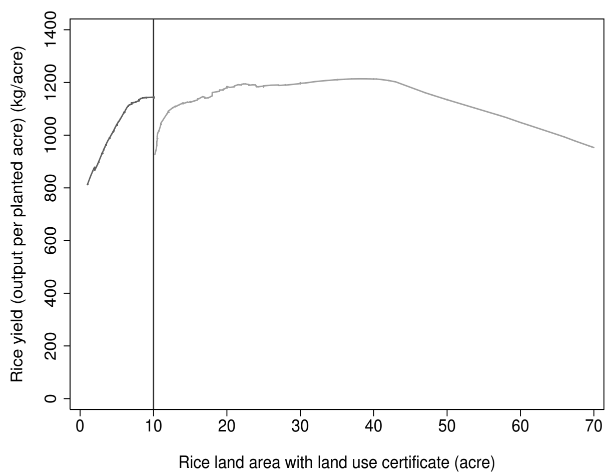
(a) Credit per acre against rice land area, both with land use certificates



(b) Rice output against rice land area with land use certificates



(c) Rice yield (kg/acre) against rice land area with land use certificates



the exclusion restriction. If the exclusion restriction holds, then we can interpret β as the causal effect of providing credit of USD 1 per acre. A key limitation of our approach is that β reflects a Local Average Treatment Effect of the MADB scheme for farmers around the threshold. We need to be cautious generalizing the estimated treatment effects to smaller and larger farmers, as this requires strong external validity assumptions that we cannot corroborate. For example, smaller and larger farmers are not expected to face the same degree of credit rationing, which would imply heterogeneous marginal effects of credit on productivity. Nonetheless, this threshold is the land size of the 60th centile farm household in our sample and located between the farm sizes of the average (11.6 acre) and median (8 acre) households.

The IV setup not only suits the fuzzy RD design but also allows us to include control variables (X_i). If the 10-acre threshold is truly arbitrary, then the exogenous control variables should be continuous in the discontinuity, once we adequately control for land size. We therefore apply balancing tests where we regress the X variables on the 10-acre threshold indicator variable D and the land size polynomial

$$X_i = \lambda_0 + \lambda D_i + \lambda_1 L_i + \lambda_2 L_i^2 + \lambda_3 L_i^3 + u_i \tag{3}$$

The set of control variables includes farm and personal characteristics (age, gender, farming experience and education level of the household head, household size, dependency ratio, perceived quality of irrigation systems, and availability of agricultural extension services), the distance to the nearest market, and regional dummy variables for Sagaing, Bago and Ayeyarwady. In principle, it is not necessary to include control variables in the IV regression if the exclusion restriction regarding the discontinuity holds. Nevertheless, including exogenous variables that explain the variation in the outcomes can reduce noise and thereby improve the precision of the estimates. In addition, it may be useful to test the sensitivity of the treatment effects to potentially confounding factors.

Finally, we need to determine the range in land size around the threshold for which we estimate Equations 1 and 2. A relatively small interval around the discontinuity will reduce precision. Taking a wide interval may resolve this but also introduce bias from farms that are far from the threshold and unsuitable comparisons for the farms below the threshold. To address this trade-off, we select an interval such that it facilitates both balancing features of the sample and the identifying power of the instrumental variable, but limits the loss of observations and precision of our estimates. We therefore asses several symmetric intervals around the threshold, the largest being 0-20 acres with the biggest sample size. However, this also includes the smallest farmers who may obscure interpretation of our estimates, as existing literature suggests that small farmers tend to use MADB credit for subsistence (LIFT, 2012), thus making it hard to disentangle the impact of credit on rice production from subsistence consumption. Taking a smaller interval, at 5-15 acres, would avoid this problem by excluding the smallest farmers but also reduce the sample size. For intervals closer around the threshold, the instrument loses statistical power, presumably due to sample size.

Balancing tests results are presented in Table 3 for the full sample and the 0-20 and 5-15 acre intervals. Controlling for a third order polynomial of land size, the full sample shows a few statistically significant differences between households below and above the threshold in X. Farmers above the threshold report on average lower quality irrigation systems, are more likely to live in Sagaing and less likely to live in Bago. When we focus on the symmetric intervals around the 10-acre threshold, then the statistical significance disappears, except for the Bago dummy variable for the 5-15 acre interval. These results suggest that the factors that matter for the outcome are continuous in the assignment variable, D_i, thereby lending credence to our fuzzy RD approach.

5. Results

5.1. Reduced form estimates

The reduced-form impacts of the threshold indicator variable D on credit per acre and various outcome variables are presented in Table 4. The coefficients are statistically significant for credit per acre, confirming the discontinuity in D_i reflected in Figure 1a. Farms larger than 10 acres receive USD 16-20 MADB credit per acre less than below the threshold, depending on the choice of interval. But for rice production and farm income from

Table 3: Balancing tests of household characteristics

VARIABLES	Full sample	0-20	5-15
Household head			
Age	1.25	-1.06	-2.13
	[1.63]	[2.61]	[2.84]
Gender (1=male)	0.05	0.02	0.01
	[0.03]	[0.06]	[0.05]
At most primary education (1=yes)	-0.05	-0.11	-0.05
	[0.09]	[0.12]	[0.07]
Secondary education (1=yes)	0.06	0.09	0.10
	[0.09]	[0.10]	[0.13]
High school/higher education (1=yes)	-0.01	0.02	-0.05
	[0.05]	[0.07]	[0.08]
Farming experience (years)	0.21	-1.62	-2.18
	[1.89]	[2.89]	[2.88]
Number of household members	-0.28	-0.30	-0.05
	[0.21]	[0.42]	[0.61]
Dependency ratio	-0.00	0.01	0.01
	[0.03]	[0.04]	[0.05]
Irrigation deemed good/very good (1=yes)	-0.14**	-0.12	-0.17
	[0.05]	[0.07]	[0.11]
Agricultural extension services (1=yes)	0.01	-0.14	-0.16
	[0.07]	[0.10]	[0.10]
Fertilizer per acre (USD)	-2.30	4.01	1.03
	[3.29]	[4.46]	[5.76]
Rice inputs excl. fertilizer per acre (USD)	0.90	0.58	-0.35
	[0.72]	[0.85]	[0.88]
Distance to market (km)	1.27	2.92	5.26
	[2.94]	[3.58]	[6.12]
Sagaing (Dry Zone) (1=yes)	0.16*	0.17	0.23
	[0.06]	[0.12]	[0.15]
Bago (Delta Region) (1=yes)	-0.11*	-0.14	-0.26*
	[0.07]	[0.11]	[0.12]
Ayeyarwady (Delta Region) (1=yes)	-0.05	-0.03	0.03
	[0.07]	[0.11]	[0.12]
Observations	628	533	290

Notes: The table shows regression coefficients of the indicator variable D (=1 if land holding size > 10). All regression control for a third degree polynomial of acres land holding with certified land use rights. Standard errors in brackets adjusted for stratification at regional level and clustering at village level. *Statistical significance:* +10%, * 5%, ** 1%.

rice production, we find no statistically significant difference for farms on either side of the threshold. Although the coefficients for rice production (total and per acre) are in line with the discontinuities observed in Figures 1b and 1c, the estimates lack precision. We do find statistical significance in total income for both the 5-15 and 0-20 intervals (at 5% and 10% level, respectively).

5.2. RD estimates

Table 5 shows fuzzy RD estimates based on the IV estimator as specified in equations (1) and (2). We find statistically significant effects of MADB credit on total income but no statistically significant effects of any other outcomes (with and without controls). The basic IV specification that controls only for the size of land holding yields an estimated effect ranging from 33-63 USD in total annual income due to 1 USD MADB credit per acre per season. The estimates are larger in magnitude but less precise for the 5-15 acres land holding interval as compared to 0-20 acres. Nevertheless, the estimates are statistically significant for both intervals. As we include control variables for farm characteristics, irrigation and regional characteristics, the results remain robust. For rice output and income, the IV estimates are not statistically significant, irrespective of the choice of specification or land holding interval.

When we disaggregate the results by region (Table 6) and control only for a third degree polynomial of acres land holding, we see that all effects on income seem to stem from the Bago region. Again, this is robust to including additional controls.[8] The estimated effects on total income in Bago are of similar magnitude as for the full sample, but statistically significant only at 10% level, presumably due to the smaller sample size. For Bago, we also find a slight positive effect of MADB credit on rice yields for the 5-15 acre interval without controls and the 0-20 interval with the controls. These results suggest that an additional 1 USD of seasonal credit per acre is associated with an increase in rice output of 6 kg per planted acre in Bago. However, this yield increase did not translate into increased rice

[8]For brevity, results with control variables are not presented but available upon request

income, either in terms of magnitude or precision of the estimates.

In general, we find no convincing evidence of MADB credit impacts on yields. One explanation could be that credit was used mostly to meet the shortage in cash before the harvest, rather than to invest in productive means. We do not have data on what exactly farmers used their credit for, but we do have information on factor inputs for rice production. Labour and fertiliser account for the bulk of the production costs. However, the IV estimates show no evidence that the MADB loans had any effect on spending on these inputs. We also find no evidence that farmers used credit to invest in high-quality varieties or mechanisation (Appendix, Table A3). These results suggest that MADB credit was not used to transform production technologies and improve rice yields. This is in line with the existing literature that finds as much as 44% of households reporting food (for consumption) purchases as the primary use of credit against only 18% households reporting the purchase of agricultural inputs (LIFT, 2012).

Another explanation for the lack of impact on rice yield is the possible focus of rice farmers on producing high-quality rice. Although we do not have data on what variety farmers planted, Ayeyarwaddy and Sagaing are the two largest regions producing Paw San rice, which is recognized as one of the world's most high-quality rice. The adoption of this variety remains relatively limited, however, since it requires more input and is more labour intensive while having a lower yield than other varieties (Myint and Napasintuwong, 2016). Meanwhile, Paw San rice is priced about 33-36 percent higher and enjoys more demand than other rice (Myint and Napasintuwong, 2016). In this situation, it is the rice income rather than rice output or rice yield that is relevant for farmers.

Having said that, we find no evidence of MADB credit impacts on rice earnings (Table 5). Again, this result is robust regardless whether controls are included or not. Results by region and in delta also lend no support that MADB credit enhances rice income (Table 6).

Table 4: Reduced form regressions for intervals of 0-20 acres and 5-15 acres

VARIABLES	Credit/acre (USD)		Rice output (kg)		Rice output per planted acre (kg)		Rice income (USD)		Total income (USD)	
	0-20	5-15	0-20	5-15	0-20	5-15	0-20	5-15	0-20	5-15
Acres land holding >10	-20.2**	-16.4*	-724	-2,155	-100	-172	-171	-282	-668+	-1,040*
	[5.2]	[6.6]	[1,742]	[1,932]	[100]	[123]	[318]	[417]	[343]	[487]
Acres land holding	-14.6	-41.9	724	18,849*	74.4	356	145	2,760	-131	573
	[9.0]	[30.2]	[696]	[9,071]	[64.6]	[422]	[126]	[1,793]	[250]	[2,2391]
Acres land holding squared	1.6	4.94	114	-2,081*	-3.4	-41.4	21.3	-295	62.2+	-40.9
	[0.94]	[3.2]	[94.3]	[1,001]	[6.9]	[45.0]	[16.7]	[199]	[34.2]	[244]
Acres land holding cubed	-0.05+	-0.18+	-4.7	80.3*	0.04	1.65	-0.81	11.3	-2.15+	2.60
	[0.03]	[0.10]	[3.3]	[34.9]	[0.2]	[1.51]	[0.60]	[7.05]	[1.15]	[8.29]
Constant	123**	195*	691	-46,914+	743**	88.4	208	-6,586	1,497**	-47.2
	[24]	[88.3]	[1,394]	[25,941]	[194]	[1,240]	[271]	[5,106]	[503]	[6,496]
Observations	533	290	533	290	533	290	533	290	533	290
R-squared	0.057	0.046	0.477	0.333	0.042	0.029	0.506	0.282	0.386	0.218
F	10.19	8.66	26.66	44.56	1.80	1.834	26.65	23.78	18.95	15.88

Notes: Acre land holding refers to farm land area with certified land use rights. Standard errors in brackets adjusted for stratification at regional level and clustering at village level. *Statistical significance:* +10%, * 5%, ** 1%.

Table 5: Instrumental variable regressions with control variables for intervals of 0-20 acres and 5-15 acres: all regions

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	0-20	5-15	0-20	5-15	0-20	5-15	0-20	5-15
Rice output (kg)	35.9	131.6	45.7	127.6	21.0	109.6	0.90	123.9
	[85.3]	[116.8]	[77.6]	[103.9]	[73.7]	[128.2]	[65.6]	[109.7]
Rice yield (kg/acre)	4.97	10.5	5.61	9.39	3.06	8.38	1.10	5.87
	[4.87]	[7.55]	[4.35]	[6.30]	[3.86]	[7.46]	[3.37]	[6.89]
Rice income (USD)	8.45	17.2	11.6	19.5	8.67	17.0	11.1	32.7
	[15.2]	[23.7]	[13.4]	[19.6]	[12.8]	[24.4]	[14.1]	[27.1]
Total income (USD)	33.10*	63.47+	31.60*	56.27*	30.87*	70.75+	33.60*	90.57+
	[15.18]	[34.57]	[14.04]	[25.91]	[13.78]	[37.56]	[15.91]	[45.07]
Control variables								
Land holding polynomial[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Farm and personal characteristics[b]	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Irrigation[c]	No	No	No	No	Yes	Yes	Yes	Yes
Regional characteristics[d]	No	No	No	No	No	No	Yes	Yes
Observations	533	290	533	290	533	290	533	290

Notes: ([a]) Land holding polynomial: a third degree polynomial of acres land holding with certified land use rights; ([b]) Farm and personal characteristics: Household head's age, gender, farming experience, education level, household size, dependence ratio, availability of extension services. ([c]) Irrigation: access to very good/good irrigation. ([d]) Regional characteristics: Distance to the market and regional dummy variables for Sagaing (Dry Zone), Bago (Delta Region) and Ayeyarwady (Delta Region).
Standard errors in brackets adjusted for stratification at regional level and clustering at village level. *Statistical significance:* +10%, * 5%, ** 1%.

Table 6: Instrumental variable regressions for intervals of 0-20 acres and 5-15 acres: by region

VARIABLES	Sagaing		Bago		Ayeyarwady		Delta	
	0-20	5-15	0-20	5-15	0-20	5-15	0-20	5-15
Rice output (kg)	143.33	176.74	23.15	81.85	-359.54	1,154.56	-96.56	-12.92
	[248.42]	[265.91]	[39.94]	[50.15]	[762.84]	[11,340.63]	[113.73]	[100.61]
Rice yield (kg/acre)	12.26	18.90	5.93	6.54+	-18.23	117.57	0.50	3.65
	[22.85]	[28.71]	[3.81]	[3.37]	[29.34]	[1,182.71]	[4.24]	[5.09]
Rice income (USD)	53.13	67.32	7.56	15.91	-24.88	-35.66	-5.94	5.46
	[104.37]	[111.68]	[9.56]	[10.17]	[82.55]	[557.43]	[15.83]	[15.99]
Total income (USD)	85.83	121.40	55.41+	72.88+	-48.31	145.56	33.58	75.58
	[137.19]	[185.73]	[24.73]	[34.57]	[93.93]	[1,456.70]	[24.28]	[49.13]
Observations	201	84	166	110	166	96	332	206

Notes: Standard errors in brackets adjusted for stratification at regional level and clustering at village level. *Statistical significance:* +10%, * 5%, ** 1%.

On the other hand, we do see a positive effect of credit on total farm income, possibly reflecting the fungibility of money. Farms plant rice because they are not in a position to make an alternative crop choice when it comes to rice land, at least not in the short term, since their crop choices are bounded by their land use certificates which require them to plant rice in at least one season. They, therefore, optimize their total farm income, not rice income or output specifically. They could have used the option of cheap credit for rice production to fund other activities that generate more profit. This is consistent with the fact that the impact of credit is most pronounced in Bago, which can be attributed to the level of income diversification and favourable location. Farms in Bago not only have relatively high incomes from rice, but they also have the highest income from other crops due to fertile land and having only one cropping season for rice as a result of the lack of water in the dry season. They also have the highest income from horticulture and non-farm services compared to their counterparts in the other two regions, possibly due to location effects. Farms in Bago are located nearer to markets (on average 6.5 km compared with 28 km in Sagaing and 16.5 in Ayeyarwady) which facilitate income activities other than rice production, thus offering more productive options for cheap credit. Furthermore, this region is one of the three most developed areas in Myanmar and close to the largest economic hub of Yangon, hence having high demand and good prices for their agricultural products.

6. Conclusion

Subsidized rural credit has long been an important tool for poverty reduction and rural development by donors and governments but its impact remains controversial. Measuring the impact of subsidized rural credit is challenging for multiple reasons. First, since money is fungible and interest rates have an economy-wide impact, it raises concerns over the objective of measuring the direct bearing on borrowers (Von Pischke and Adams, 1980; Adams, 1988). Second, even in a partial equilibrium framework where the impact on borrowers is possibly the only concern, observable data on the outcome of credit programs contain many confounding factors such as selection bias and the targeting nature of the programs. As a result, despite a significant number of studies have been devoted to evaluating credit projects, not many are deemed as rigorous. Meanwhile, the rigorous studies rely on data which is either from rare natural experiments or from highly resources intensive RCT. Even in these cases, the evidence is highly contextual and limited to the impact of marginal borrowers, not infra-marginal borrowers, hence giving little justification for existing programs.

This paper aims to contribute rigorous evidence to the existing literature. In particular, we evaluate the impact of a long-lasting large-scale subsidized rice credit in Myanmar, a poor and, until recently, isolated country. Taking advantage of an arbitrary eligibility rule for credit provision, we apply a fuzzy RD approach to overcome endogeneity caused by potentially confounding characteristics that affect both rice production and the amount of credit received. We find little evidence that the program's target of increasing rice yield and output is achieved. Nonetheless, we do see an impact of the program on total household income, suggesting its positive spillover effects on other farm income activities.

Due to the use of the fuzzy RD approach, our evidence reflects only the local average treatment effect of the program for farmers around the threshold of eligibility. Nonetheless, while we are cautious about generalizing the treatment effects for all farms in the sample, we would like to emphasize that the effect is found for households in the middle of the distribution, and is robust to the inclusion of various control variables and different intervals around the discontinuity. Finally, since the IV estimator of the fuzzy RD approach has large sample properties, a significant improvement in this work would be to increase the sample size to enhance its precision.

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Supplementary appendix

Table A1: First stage regressions for credit per acre at different intervals around the discontinuity

VARIABLES	(1) Full sample	(2) 0-20 acres	(3) 5-15 acres	(4) 7-13 acres
Acres land holding > 10	-6.07	-20.18**	-16.38*	-19.14+
	[6.39]	[5.19]	[6.61]	[11.11]
Acres land holding	-1.54	-14.56	-41.93	-208.10
	[1.72]	[9.02]	[30.23]	[321.89]
Acres land holding squared	0.00	1.59	4.94	22.31
	[0.05]	[0.94]	[3.17]	[31.87]
Acres land holding cubed	0.00	-0.05+	-0.18+	-0.77
	[0.00]	[0.03]	[0.10]	[1.03]
Constant	95.62**	123.28**	195.15*	711.45
	[11.06]	[24.04]	[88.30]	[1,060.11]
Observations	628	533	290	169
R-squared	0.167	0.057	0.046	0.056
F	36.06	10.19	8.660	3.177

Notes: Acre land holding refers to farm land area with certified land use rights. Standard errors in brackets adjusted for stratification at regional level and clustering at village level.
Statistical significance: +10%, * 5%, ** 1%.

Table A2: Instrumental variable regressions with control variables for all regions for intervals 0-20 acres and 5-15 acres: inputs used

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	0-20	5-15	0-20	5-15	0-20	5-15	0-20	5-15
Hired labour (USD)	-1.62	3.90	-0.42	4.59	-1.33	3.49	-1.60	5.04
	[4.51]	[6.65]	[3.98]	[5.37]	[3.95]	[6.80]	[4.55]	[8.56]
Family labour (USD)	0.43	0.15	-0.40	-0.04	-0.46	-0.02	-0.60	0.33
	[1.81]	[3.04]	[1.47]	[2.35]	[1.50]	[3.24]	[1.68]	[4.18]
Fertilizer/planted acre (USD)	-0.20	-0.06	-0.06	0.10	-0.08	0.06	0.03	0.52
	[0.24]	[0.36]	[0.18]	[0.26]	[0.19]	[0.36]	[0.21]	[0.52]
Non-fertilizer expenses/planted acre (USD)[a]	-0.03	0.02	-0.02	0.03	-0.02	0.05	-0.00	0.11
	[0.04]	[0.05]	[0.03]	[0.05]	[0.04]	[0.07]	[0.04]	[0.11]
Control variables								
Land holding size polynomial[b]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Farm and personal characteristics[c]	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Irrigation[d]	No	No	No	No	Yes	Yes	Yes	Yes
Regional characteristics[e]	No	No	No	No	No	No	Yes	Yes
Observations	533	290	533	290	533	290	533	290

Notes: ([a]) Non-fertilizer expenses include expenses on new seed varieties, draught animals, tools, equipment and machines among others; ([b]) Land holding polynomial: a third degree polynomial of acres land holding with certified land use rights; ([c]) Farm and personal characteristics: Household head's age, gender, farming experience, education level, household size, dependence ratio, availability of extension services. ([d]) Irrigation: access to very good/good irrigation. ([e]) Regional characteristics: Distance to the market and regional dummy variables for Sagaing (Dry Zone), Bago (Delta Region) and Ayeyarwady (Delta Region).
Standard errors in brackets adjusted for stratification at regional level and clustering at village level. *Statistical significance:* +10%, * 5%, ** 1%.

Table A3: Instrumental variable regressions for inputs used in rice production by region

VARIABLES	Sagaing		Bago		Ayeyarwady		Delta	
	0-20	5-15	0-20	5-15	0-20	5-15	0-20	5-15
Hired labour (USD)	10.55	24.26	-7.20	-0.79	-7.39	33.83	-8.95	-5.88
	[21.26]	[33.52]	[7.27]	[6.60]	[23.07]	[407.77]	[7.65]	[9.99]
Family labour (USD)	1.85	2.75	1.75	1.28	-5.64	65.60	-0.01	-1.77
	[5.69]	[9.15]	[1.59]	[1.37]	[15.85]	[678.94]	[3.40]	[5.31]
Fertilizer/planted acre(USD)	1.14	1.86	0.08	0.30	-1.82	8.15	-0.45	-0.27
	[1.80]	[2.32]	[0.16]	[0.20]	[2.41]	[82.87]	[0.36]	[0.44]
Non-fertilizer expenses/planted acre (USD)	0.18	0.38	-0.03	-0.02	-0.28	0.98	-0.09	-0.06
	[0.29]	[0.48]	[0.04]	[0.05]	[0.38]	[10.25]	[0.05]	[0.05]
Observations	201	84	166	110	166	96	332	206

Standard errors in brackets adjusted for stratification at regional level and clustering at village level. *Statistical significance:* +10%, * 5%, ** 1%.