EFFECT OF FARM SIZE ON FARM PRODUCTIVITY:

EMPIRICAL EVIDENCES FROM INDIA

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ABSTRACT

Our study provides evidence on land tenure related issues in India. We use the Village Dynamics in South Asia (VDSA) panel dataset for the years 2010 to 2015 covering 1129 households in 9 states of India. We specifically test two hypotheses: 1) plot size is positively related to farm productivity; 2) owner operated lands have higher farm productivity. We calculate Hierarchical Mixed Effects Models in order to take the nested structure of the data into account. Transformation parameters are included in order to accommodate non-linear relationships between our variables. Our results confirm a positive relation between the average plot size and the agricultural productivity from cultivation. They provide supporting arguments for key aspects of ongoing land reform processes in India. In particular the land consolidation and ceiling policies should support an increase in agricultural productivity.

INTRODUCTION

More than half of the rapidly growing population in India is engaged in farming. Chakravorty et al. (2016) show that: (a) income inequality in India's agricultural sector is very high, and (b) about half of the income inequality is explained by the household-level variance in income from cultivation, which in turn strongly depends on farming productivity and land tenure. Inheritance rules which lead to ever new subdivision of land holdings continue to increase the number of parcels (Thapa et al., 2008). There is much evidence that this land fragmentation negatively affects agricultural productivity as it increases production cost (Manjunatha et. al., 2013; Deininger et al., 2017). At the same time it can reduce parcel related risks (Ali et al., 2015). It is a common phenomenon in India that a household has a reasonable operated agricultural land area which is split into small scattered units. In response to the widely acknowledged challenges, the Government of India introduced policies and laws to consolidate fragmented land holdings (Ghatak and Roy, 2007). The objective of the consolidation process is to merge smal1 scattered pieces of land into compact units. There are divergent opinions in the literature on the

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relation between farm size and productivity. Some provide evidence of the inverse relation (e.g. Sial et al., 2012; Banerjee, 1999; Sen, 1966; Mazumdar, 1963; C.H.H. Rao, 1966, 1970), whereas others argue that no systematic relationship can be established between land size and productivity (e.g. A.P. Rao, 1967, Rudra and Bandopadhyay, 1973). Besley and Burgess (2000) claim that India's land consolidation has had a positive impact on agricultural productivity.

Land tenure security in connection to the relation between land owners and tenants is another major challenge in the Indian agriculture. Many plots are not farmed by owners but by tenants under short-term, informal, often oral lease agreements. Land owners hesitate to formalize lease agreements as the current land legislation gives strong rights to long-term tenants. The owners are quickly at risk of losing their land rights to the tenants. This land tenure situation provides little incentives for tenants to make even moderate investments. There is empirical evidence that households managing owned land are more productive and having higher income than households managing leased plots (Smith, 2004; Walker et. al., 1988).

With this study we intend to deepen the understanding of the link between land tenure and farm productivity in India. We are not studying land reform schemes of any kind but assess to which extend variables which are typically the target of land reform projects affect different outcome variables. We use the Village Dynamics in South Asia (VDSA) panel dataset for the years 2010 to 2015 covering 1129 households in 9 states of India. We test hypotheses related to farm productivity, plot size and agricultural management which are discussed in the next section.

HISTORICAL EVIDENCE AND THEORETICAL CONSIDERATIONS

In pre-independent India, Zamindars were the large landowners with tax collection rights (Ghatak and Roy, 2007). British authorities did not reform land tenure during colonial times. Only after independence, serious efforts were made to reform land tenure. As per the first five year plan, land reform was considered a fundamental issue of national importance. Primarily, four elements constitute land reform legislation in India: tenancy reform, abolition of intermediaries, land ceiling and land consolidation. These reforms were enacted with four primary objectives: 1) to improve the productivity of land by improving incentives for farmers and tenants to invest in and improve agricultural land; 2) to ensure distributive justice and to create an egalitarian society by eliminating all forms of exploitation; 3) to create a system of peasant proprietorship with the motto of land to the tiller; and 4) to transfer the incomes of the few to many so that the demand for consumer goods would be created (GOI, 2015). In this paper we focus mainly on the productivity objective while keeping the other objectives closely in mind.

An important historical milestone of improving productivity through land consolidation was the Zamindari Abolition and Land Reform Act, 1951 which led to the Consolidation of Holdings Act, 1953 being implemented in many states like Punjab, Uttar Pradesh, Haryana, West Bengal and Kerala. Other relevant laws are the Bombay Prevention of Fragmentation and Consolidation of Holdings Act, 1948 (GOI, 1948a); the East Punjab Holdings (Consolidation and Holding) Act, 1948 (GOI, 1948b); The UP Consolidation of Holdings Act, 1953 (GOI, 1953); The Rajasthan Holdings (Consolidation and Prevention of Fragmentation) Act, 1954 (GOI, 1954); The Madhya Pradesh Land Revenue Code, 1959 (GOI, 1959); The Jammu and Kashmir Consolidation Holdings Act, 1962 (GOI, 1962) etc. Similar laws were enacted in Bihar (1956) (GOI, 1956), Asom (1960), Andhra Pradesh (1956), Himachal Pradesh (1953) (GOI, 1971) and other states during 1970s.

Typical measures to prevent fragmentation and encourage consolidation of holdings are: 1) very small plots may only be transferred to owners of neighbouring plots; 2) very small plots may only be leased out to farmers cultivating neighbouring plots; 3) land may not be partitioned and transferred in a way that a small land fragment is created (GOI, 1948). In addition, the state government on its own initiative or upon the request of at least seven farmers owning land not exceeding 0.4 ha can initiate land consolidation projects. The government may acquire land which is fragmented against paying compensation, rearrange the plots into consolidated units and reallocate them to farmers whose land has been acquired. The reallocation needs to ensure that farmers get land of similar quality and value (GOI, 1999).

State governments typically take the following steps in the process of land consolidation schemes: 1) Select the district or local area to conduct consolidation. (2) Notify land owners and managers about the upcoming consolidation process. After this notification is given, transfers of land are prohibited. The announcement also gives farmers the chance to postpone major investments into land. In addition, the consolidation office is officially assigned with the responsibility for all matters related to the preparation and correction of the annual land registers and maps. 3) The Consolidation Officer visit each of the concerned villages and shall, in consultation with the village committee proceed to prepare a scheme for the consolidation of holdings which include statements, records and maps as may be prescribed. 4) The allotment of plots would be determined based on rental values (Elder, 1962).

By 2006, more than 660.000 km^2 of fragmented land has been consolidated all over India. Strongest efforts were made in northern Indian states such as Uttar Pradesh, Haryana and Punjab (ICAR, 2017). Nevertheless, there are frequent reports about farmers being reluctant to land consolidation in view of the uncertainty whether they would be allotted land of equally good quality in return for their parcels that they were forced to sell or swap with the land of fellow farmers (Thapa and Niroula, 2008). Soil

heterogeneity is a critical factor hindering exchange of plots. Walker et. al. (1988) observe that land consolidation was more likely to be successful in areas with more homogeneous soils such as in the north western parts of India.

A case study of the village Rajpur in Uttar Pradesh documents a decrease in agricultural production in the initial years after consolidation. This negative effect was associated with uncertain perceptions of farmers as to whether the government would indeed implement the consolidation scheme. Nevertheless, the study also suggests that after the initial adjustment phase the land consolidation supported productivity increases (Elder, 1962).

Bonner (1987) reported in a private sector funded study of two villages in Haryana an increase of land productivity at the family level in relation to the implementation of a land consolidation scheme. He further observed a reduction of landless farmers and lower incidences of land disputes. On the community level the cultivated area expanded, a larger area became irrigated, more intensive agricultural practices were used and farmers moved more strongly towards producing cash crops. This effect was partially financed by credits and the households' debt burden increased. It was reported that the education levels and general standard of living of farmers improved. A regional market economy replaced the previous strong subsistence orientation.

We believe that more evidence is required to better understand the causalities related to land consolidation. Based on impacts reported in the literature we formulate the following hypotheses which will be tested using our panel dataset:

> H1) The average plot size is positively related to the productivity of cultivation activities as well as to the overall agricultural productivity (including livestock). The marginal productivity gain decreases with increasing plot size.

The formal expression is:

Eq1: $Y_{it} = \beta_1 + \beta_2 X^{r}_{2it} + \beta_3 X^{s}_{3it} + \beta_4 X_{4it} + u_{it}$

where Y_{it} represents

> the productivity of land exclusively from cultivation activities computed as the net income from crop cultivation (returns to land, family labor and management) divided by the operated area (INR/ha) OR

the productivity of all agricultural activities computed as the net income from crop cultivation plus the net income from livestock production divided by the operated area (INR/ha),

i stands for the household and t for the observed year,

X_{2it} represents the average plot size of i^{th} household in year t,

X_{3it} represents the operated area of household i in year t,

X_{4it} is a vector of controls namely: non-land endowment in 2010, income diversity, age of household head, years of education of household head, member of scheduled caste or tribe, net state domestic product, ratio of operated area used to grow cash crops, work hours per hectare, annual rainfall in mm and

u_{it} is the error term.

Transformation parameters r and s are included in order to accommodate non-linear relationships between the variables.

Our data also allow us to look deeper into intermediary effects which are influenced by land consolidation and which affect agricultural productivity. Multiple advantages of establishing compact blocks of land managed by one family are reported: boundary lines would be reduced in number and extent, saving land and diminishing boundary disputes; saving time related to commuting to the fields; realising economies of scale related to mechanisation. Further, costs per hectare are lower to protect larger pieces of land by natural or artificial borders in order to prevent trespassing, thieving, and gleaning. This could encourage more investments into the land. Also, the management of irrigation and drainage water as well as of pests and disease would be easier (Elder, 1962). Inspired by such arguments we formulate and test the following hypotheses:

H2) The larger the average plot size the higher the machinery investments.

H3) The larger the average plot size the more investments in water infrastructure are made.

H4) The larger the plot size higher is the farm equipment owned by the household.

H5) The larger the average plot size the more intensive the pest and disease control.

The formal expressions of H4 and H5 are:

Eq2: $$Y_{it} = \beta_1 + \beta_2 X^{r}_{2it} + \beta_3 X^{s}_{3it} + \beta_4 X_{4it} + u_{it}$$

where Y_{it} represents the

the total value of owned farm equipment in constant prices INR OR

the value of pesticide used per ha in constant prices INR

i stands for the household and t for the observed year,

X_{2it} represents the average plot size of i^{th} household in year t,

X_{3it} represents the operated area of household i in year t,

X_{4it} is a vector of controls namely: non-land endowment in 2010, income diversity, age of household head, years of education of household head, member of scheduled caste or tribe, net state domestic product, ratio of operated area used to grow cash crops, work hours per hectare, annual rainfall in mm and

u_{it} is the error term.

The formal expressions of H2 and H3 are:

$$Pr(Y_{it} = 1 \mid x_{it}) = F(\beta_1 + \beta_2 X^{r}_{2it} + \beta_3 X^{s}_{3it} + \beta_4 X_{4it})$$

where Y_{it} represents

the use of tractor OR

the access to a bore well by household i in year t

i stands for the household and t for the observed year,

X_{2it} represents the average plot size of i^{th} household in year t,

X_{3it} represents the operated area of household i in year t,

X_{4it} is a vector of controls namely: non-land endowment in 2010, income diversity, age of household head, years of education of household head, member of scheduled caste or tribe, net state domestic product, ratio of operated area used to grow cash crops, work hours per hectare, and annual rainfall in mm.

In addition to the impact of plot size, we are also interested in the role of land ownership. Secure ownership rights support that today's investments will generate future returns (Meinzen-Dick and

Pradhan, 2002; Fenske, 2011) and are, therefore, long-term incentives for investing in and maintaining resources (Demsetz, 1967; Place, 2009). Higher levels of investment should theoretically lead to productivity increases (Holden and Yohannes, 2002; Smith, 2004). In addition, land titles are often accepted as collateral and, in this way, should facilitate access to credit (Deininger, 2003; Place, 2009; Fenske, 2011). Financial organisations prefer land as security because the risk of losing the asset creates commitment, which helps to take the contracting partner seriously (De Soto, 2000). Many Indian states made efforts to transfer ownership rights to tenants. By the end of 2010, 12.586 million tenants received secure land titles covering 67637.89 sq. km (ICAR, 2017).

Despite very logical theoretical relations, the empirical evidence on the link between property rights and land productivity is very ambiguous, confusing and contradictory (Carter and Olinto, 2003; Smith, 2004; Bromley, 2009; Do and Iyer, 2008; Markussen, 2008; Place, 2009; Besley and Ghatak, 2010; Fenske, 2011). Some studies claim that reforms in tenancy laws resulted in enhanced productivity in most states (Banerjee et al., 1998; Banerjee et.al., 2002; ICAR, 2017). Banerjee et al. (1998) argue that increasing security of leasehold rights encourages investment by the tenants. Deininger et. al. (2009) stated that land reforms had a significant and positive impact on income growth and accumulation of human and physical capital in India (see also Manjunatha et. al., 2013). Nevertheless, Ghatak and Roy (2007) rather see a significant negative effect of reforms in tenancy laws on agricultural productivity. They further observe increased inequality in operational land holdings. Walker et al. (1988) found in their study of Indian semi-arid villages no evidence for an economic polarization in relation to the ownership of land. Nevertheless, they observed that mixed tenants cultivated own land significantly more intensively than the land they sharecropped. Suboptimal utilization of labour and bullock draft per unit of land in tenant farms was the main reason for this inefficiency. We use our available data to test our last hypothesis.

> H6) There is a high positive correlation between the size of land owned as well as the share of the operated area owned and the farm productivity, the access to credit and the investments in non-land assets.

DATA AND METHODOLOGY

We use the Village Dynamics in South Asia (VDSA) panel dataset generated by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in partnership with Indian Council of Agricultural Research (ICAR) Institutes. We use VDSA data collected between 2010 and 2015 in 30 villages of 9 states of India (Andhra Pradesh, Bihar, Gujarat, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha and Telangana). The sampling followed a stepwise strategic approach. First of all, the sample covered six agro-ecological zones of the semi-arid and humid tropics of India defined by the

Length of Growing Period (FAO, 1996). Typical districts within the agro-ecological zones were selected based on soil and climate parameters. An additional criterion for the district selection has been that a significant share of the agricultural land is used to cultivate ICRISAT mandate crops (sorghum, pearl millet, pulses and groundnuts). A similar strategy was used to select two villages within each chosen district. Figure 1 illustrates the location of the VDSA villages. In each of the 30 villages 40 households were selected based on a stratified sampling. Baseline surveys were used to classify households according to their land holding (landless, small, medium and large landholding groups). Households within each of these groups were drawn randomly (Binswanger and Jodha, 1978; Rao et al., 2015). In this particular study we only use data of VDSA households who are actively cultivating any land.

Figure 1 about here

The VDSA dataset contains a wide range of variables related to agriculture and rural development. All questionnaires are accessible under http://vdsa.icrisat.ac.in/vdsa-microdoc.aspx. Intensively trained village resident investigators periodically revisit the same households over the years to collect the data.

We calculate Fixed Effects and Hierarchical Mixed Effects Models in order to take the nested structure of the VDSA data into account. We suspect non-linear relations between agricultural productivity and plot size as well as operated area. We use the Fractional Polynomial (fp) procedure implemented in STATA 14 in order to find best fitting variable transformations (Royston and Sauerbrei, 2008). F-tests are used to identify the best fitting variable transformations.

RESULTS

Half of our sample households operate fields of less than 1.2 ha and 95 percent manage less than 6.5 ha. The plot size is on average 0.6 ha (Figure 2). The average annual income per ha from cultivation in constant prices was approximately USD 580. Taking all agricultural activities into account, the income per hectare was on average USD 800.

Figure 2 about here

Hardly any of the household heads in our sample is female. This is the reason why sex is not controlled for in our analyses. The household heads are on average 49 years old and went five years to school. Farmers have a cash crop ratio of on average 30 percent. We take into account the overall economic environment by controlling for the Per capita net state domestic product. There is a high variance in this value with a minimum of below USD 350 in year 2013 for the state Bihar and more than USD 2300 in

year 2012 for the state Maharashtra. Also the agro-ecological conditions are very diverse in our sample. We take this into account by controlling for the rainfall (Table 1).

Table 1 about here

The mixed effects models (Table 2) reveal a steep decline of productivity for very small plots. Already at a plot size below half a hectare the marginal effect is very small (Models 1 and 2, Appendix 2). Nevertheless, the plot size of more than half of our sample is in this very small range (Figure 2). At the same time, we observe a steep decline in productivity as the total operated area of the household increases in the range of the operated area managed by most of our households (<6 ha). The effect fades out for larger farms (Models 1 and 2, Appendix 2).

Our results further indicate that younger farmers are more productive at least when taking all agricultural activities into account. A higher level of formal education did, however, not contribute to higher productivity. Structurally disadvantaged groups are less productive. The households endowment with physical capital measured in non-land assets positively affects agricultural productivity. The overall economic environment had no significant impact (Models 1 and 2).

Table 2 about here

The models in Table 3 indicate that farmers with larger plots more likely use tractors while especially owners of smaller plots use a borewell. The value of pesticide used per ha is high especially for very small plots while marginal effect fades out for moderate plot sizes. We observe a higher probability of tractor use amongst structurally disadvantaged households, despite the fact that they have an overall lower physical capital base. They also use less pesticides. In general, the physical capital base positively affects the probability of using a tractor or owning a bore well. Farmers growing cash crops more often use tractors and pesticides. Tractor usage is more frequent in economically strong states while bore wells are more common in the poor ones. The Random effects parameters indicate a rather low sample variance on the state level but a high one on the village and household level.

Table 3 about here

Our correlation analyses shows that households owning more land have a higher household income from agriculture but surprisingly a lower productivity (taking all agricultural activities into account). There is a positive correlation between physical and natural capital. Land ownership supports credit access. The more land a household owns the more it leases out. Interestingly, the lower the agricultural productivity

the more likely the household leases out land (Pairwise correlation coefficient = -0.0455, 1 percent significance level). Farmers operating larger areas lease a larger share of it (Table 4).

Table 4 about here

DISCUSSION

Referring to Hypothesis 1, we observe a strong impact of a household's plot size on the agricultural productivity in the range of very small plots. Half of the households in our sample manage such small plots of less than half a hectare. Confirming Hypothesis 2, tractors are more likely used on larger plots while we find no relation to farm equipment in general (H4). The value of agricultural inputs is higher rather on smaller plots (H5). We assume this can be explained by less efficient use e.g. of fertilisers and pesticides. Surprisingly, also borewells are more frequent on smaller plots (H3). Probably larger plots require different irrigation techniques. The effect of the plot size on the agricultural productivity is negligible for plot sizes above half a hectare. Our results support land consolidation policies of really small land holdings.

At the same time, we see steep productivity decreases in the range of small operated areas. It is a common observation that agricultural productivity decreases with increasing land size (Heltberg, 1998; Mazumdar, 1963; Sen, 1964, 1966; C.H.H. Rao, 1966, 1970; Bhattacharya and Saini, 1972; Manjunatha et. al., 2013). Small farms are more efficient especially in poor, labour abundant agricultural systems (Bhalla and Roy, 1988; Hazell, 2005). Ghatak and Roy (2007) come to contrasting conclusions arguing that the Indian land ceiling legislation had a negative impact on farm productivity. We cannot make any statements about the impact of land ceiling policies but we find evidence in our data set for decreasing farm productivity as the operated area increases. This can be interpreted as support for land ceiling in general.

Though land ownership facilitates credit access and is positively related to physical capital, it does not have a positive effect on agricultural productivity (H6). This raises the question why land owners cannot capitalise on the better incentive structures related to secure land tenure. Land ownership seems to allow the emergence of land markets. Less productive land owners in our sample more likely lease out land. This is in result with other evidence indicating that well-functioning leasehold markets increase the productivity of agriculture (Deininger, 2003). They enable the transfer of land eventually to the most productive user (Place, 2009, Fenske, 2011). Our results should not be interpreted as an argument that improving land tenure security is of low importance in India. The authors strongly believe that the opposite is the case. For us it rather indicates further research needs to better understand why the positive effects of land ownership do not translate into improved productivity in India.

CONCLUSION

Our results provide supporting arguments for key aspects of land reform processes in India. In particular the land consolidation and ceiling policies should support an increase in agricultural productivity. We repeat the call of Walker et. al. (1988) from 30 years ago to invest in consolidating fragmented land plots and avoiding further fragmentation. The focus should be on really tiny plots as losses are highest there. There are promising trials of alternative approaches where fragments are not formally exchanged but where cooperation between neighbouring farmers is supported to reduce the negative effects of small plots. Chowdry et al. (2000) report on a project in Andhra Pradesh implemented by the state government which promotes and demonstrates flexible cooperative agricultural frameworks. It tries to create cooperate management of pooled individual land holdings. Nevertheless, also these trials face many challenges.

Our study provides another evidence for the observation that small farmers are more productive. This leads to the conclusion that land ceiling leads to higher outputs on the large scale, decreases the yield gap and reduces wealth inequalities. The result is an indication that Indian agriculture is still marked by low cost of labour (compare with Bhalla and Roy, 1988). We observe at the same time significant increases of rural labour costs over the last years. It will be interesting to see whether this development will change the relation between farm size and productivity in future.

Further research is required to better understand why land owners do not manage to translate the advantages of holding land titles into higher productivity. They have better credit access and better physical capital. Still, the productivity is even rather lower than the one of leasehold farmers.

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TABLES

Table 1: Descriptive statistics of the variables used in regressions; source: own calculations

Variables	Obs	Mean	Std. Dev.	Min	Max
Age of the household head in years	4,225	49	12	16	90
Years of education of household head	4,221	5	5	0	19
Average of household's plot size in ha	3,971	0.59	0.6	0	5
Operated area per household in ha	4,225	2.05	2.8	0	36
Share of operated area which is owned by household	4,225	0.89	0.3		
Number of income sources	4,225	4.3	2	0	10
Annual average household income from cultivation per ha in constant prices (USD/ha)	4,173	580	830	-4188	21819
Annual average household income from all agricultural activities per ha in constant prices (USD/ha)	4,130	864	1435	-12635	39494
Ratio of cash crops in total cropped area	3,960	0.3	0.4		
Per hectare working hours dedicated to cultivation of a household per year	3,965	742	762	3	20419
Value of non-land household assets in 2010 ('000 USD)	4,225	6	8	0.15	94
Per capita net state domestic product (USD)	4,225	1144	526	331	2219
Annual rainfall in the village in millimeters	4,194	768	322	86	2132

Table 2: Mixed-Effects models describing the productivity of households between 2010 and 2015; all monetary values in constant prices; standard errors in parentheses; *p<0.05, **p<0.01, ***p<0.001; source: own calculations

	Model 1 HH income from cultivation per ha in INR	Model 2 HH income from all agricultural activities per ha in INR
1 / Average plot size in ha	-1063* (420)	-2861*** (758)
ln of operated area in ha	-6774**(2132)	-18333*** (3704)
Age of head in years	-29.48 (47.64)	-279.6** (91.42)
Years of education of household head	-135.3 (159.6)	-474* (218)
SC/ST caste (1=SC/ST)	108.6 (873.3)	-21741* (10568)
Non-land assets in 2010 in INR	0.011** (0.004)	0.015*** (0.005)
Income diversity	-15446*** (2410)	-8954 (5811)
Ratio of cash crops in total crop area	13321* (66287)	10058 (8230)
Work hours per hectare	15.76** (5.66)	16.25*** (4.702)
Annual rainfall in mm	9.230** (3.382)	9.681* (4.543)
Per capita NSDP in INR	0.0725 (0.177)	0.150 (0.159)
Constant	12821 (13068)	44720** (15585)
Random effects parameters State	9.205^{***} (0.415)	9.520^{***} (0.378)
Random effects parameters Village	9.576^{***} (0.302)	9.885^{***} (0.127)
Random effects parameters Household	10.85^{***} (0.166)	10.91^{***} (0.140)
Random effects parameters Residual	10.81^{***} (0.106)	11.10^{***} (0.0954)
Observations	3923	3880
No. of household observations	1124	1121

Table 3: Models describing agricultural management and assets aspects; all monetary values in constant prices; standard errors in parentheses; *p<0.05, **p<0.01, ***p<0.001; source: own calculations

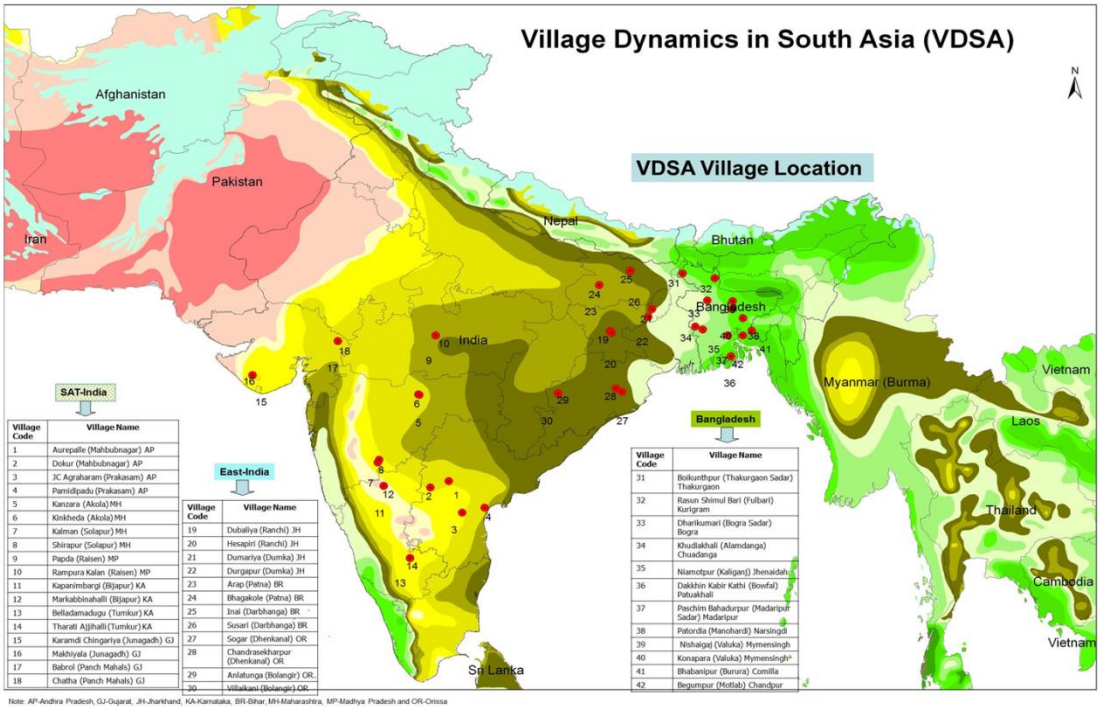
	Model 3 Using tractor (logit model)	Model 4 Having borewell (logit model)	Model 5 Total farm equipment value in INR (mixed-effects model)	Model 6 Value of pesticide used per ha in INR (mixed-effects model)
Average plot size in ha	4.643*** (0.79)	-1.484*(0.634)	11576.9 (10896.8)	
1 / Average plot size in ha				-6.250* (2.840)
Operated area in ha	-0.0155 (0.150)	0.108 (0.107)	16487.5*** (1473.2)	5.616 (3.236)
Age of HH head in years	0.027** (0.010)	0.0089 (0.030)	-29.52 (204.9)	-1.407 (1.298)
Years of education of household head	0.048 (0.026)	0.112 (0.0876)	1684.6 (886.1)	-2.450 (1.903)
SC/ST caste (1=SC/ST)	1.695** (0.603)	-1.972 (1.872)	-10381.0** (3414.8)	-45.27* (17.74)
Non-land assets in 2010 in 1000 INR	0.001* (0.0005)	0.01*** (0.003)		0.006 (0.023)
Income diversity	1.088** (0.361)	1.248 (0.763)	-8562.4 (19474.6)	-32.33 (70.69)
Ratio of cash crops in total crop area	2.216*** (0.57)	0.288 (0.670)	15317.1 (10401.5)	169.7* (81.45)
Weeks of work per ha	-0.003 (0.006)	0.025* (0.01)	220.0 (135.1)	13.63** (4.454)
Annual rainfall in 100 mm	0.0399 (0.0267)	-0.239*** (0.05)	-568.7 (692.6)	4.634 (5.131)
Per capita NSDP in 1000 INR	0.074*** (0.01)	-0.056*** (0.01)	-270.5 (200.9)	-0.164 (1.205)
Constant	-4.90*** (0.72)	-6.697* (3.012)	6085.1 (23265.6)	135.6 (96.94)
Panel-level variance	1.379*** (0.2)	4.696*** (0.23)		
Random effects parameters State			-1.172 (1353.7)	-3.598 (63.74)
Random effects parameters Village			9.937*** (2.337)	5.209*** (0.21)
Random effects parameters Household			11.21*** (0.635)	5.050*** (0.55)
Random effects parameters Residual			11.18*** (2.372)	6.452*** (0.32)
Observations	3927	3927	3092	3928
No. of household observations	1,072	1,072	1,054	1,125

Table 4: Pairwise correlation coefficients of land ownership and related variables; all monetary values in constant prices; (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); source: authors

	Total area owned by HH in ha	Share of operated area which is owned by HH
Share of operated area which is owned by HH	0.1479*	
HH income from cultivation in INR	0.5505*	-0.0469*
HH income from cultivation per ha in INR	-0.02	-0.004
HH income from all agricultural activities in INR	0.5613*	-0.0577*
HH income from all agricultural activities per ha in INR	-0.0542*	0.013
Net material (non-land) asset value in INR	0.1602*	-0.0195
Value of HH liabilities in INR	0.3645*	-0.0039
Operated area of HH in ha	0.8947*	-0.1027*
HH's leased out land in ha	0.2832*	0.0561*

FIGURES

Figure 1. Survey locations of the VDSA data (this study focuses on the Indian sites only), *Source:* www.vdsa.icrisat.ac.in

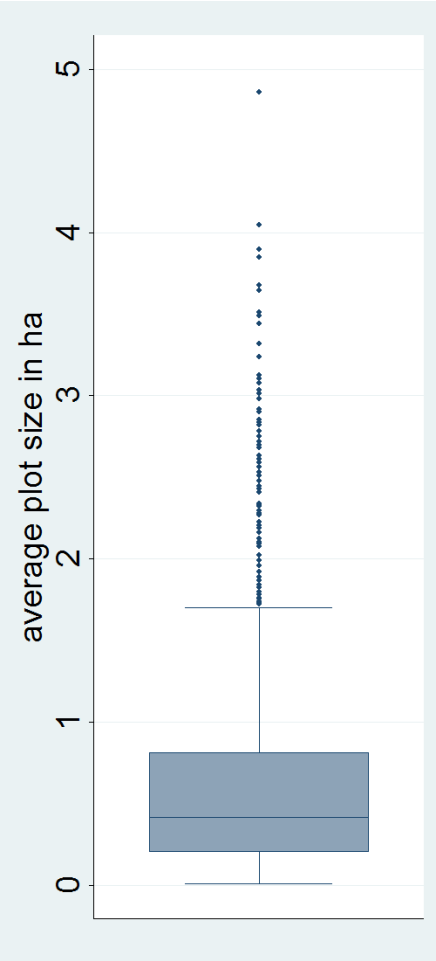


Village Code	Village Name
1	Aurepalle (Mahbubnagar) AP
2	Dokur (Mahbubnagar) AP
3	JC Agraharam (Prakasam) AP
4	Pamidipadu (Prakasam) AP
5	Kanzara (Akola) MH
6	Kinkheda (Akola) MH
7	Kalman (Solapur) MH
8	Shirapur (Solapur) MH
9	Papda (Raisen) MP
10	Rampura Kalan (Raisen) MP
11	Kapanimbargi (Bijapur) KA
12	Markabbinahalli (Bijapur) KA
13	Belladamadugu (Tumkur) KA
14	Tharati Ajjihalli (Tumkur) KA
15	Karamdi Chingariya (Junagadh) GJ
16	Makhiyala (Junagadh) GJ
17	Babrol (Panch Mahals) GJ
18	Chatha (Panch Mahals) GJ

Village Code	Village Name
19	Dubaliya (Ranchi) JH
20	Hesapiri (Ranchi) JH
21	Dumariya (Dumka) JH
22	Durgapur (Dumka) JH
23	Arap (Patna) BR
24	Bhagakole (Patna) BR
25	Inai (Darbhanga) BR
26	Susari (Darbhanga) BR
27	Sogar (Dhenkanal) OR
28	Chandrasekharpur (Dhenkanal) OR
29	Anlatunga (Bolangir) OR
30	Villalkani (Bolangir) OR

Village Code	Village Name
31	Boikunthpur (Thakurgaon Sadar) Thakurgaon
32	Rasun Shimul Bari (Fulbari) Kurigram
33	Dharikumari (Bogra Sadar) Bogra
34	Khudiakhali (Alamdanga) Chuadanga
35	Niamotpur (Kaliganj) Jhenaidah
36	Dakkhin Kabir Kathi (Bowfal) Patuakhali
37	Paschim Bahadurpur (Madaripur Sadar) Madaripur
38	Patordia (Manohardi) Narsingdi
39	Nishaigaj (Valuka) Mymensingh
40	Konapara (Valuka) Mymensingh
41	Bhabanipur (Burura) Comilla
42	Begumpur (Motlab) Chandpur

Figure 2: Average plot size in ha of VDSA sample; source: authors

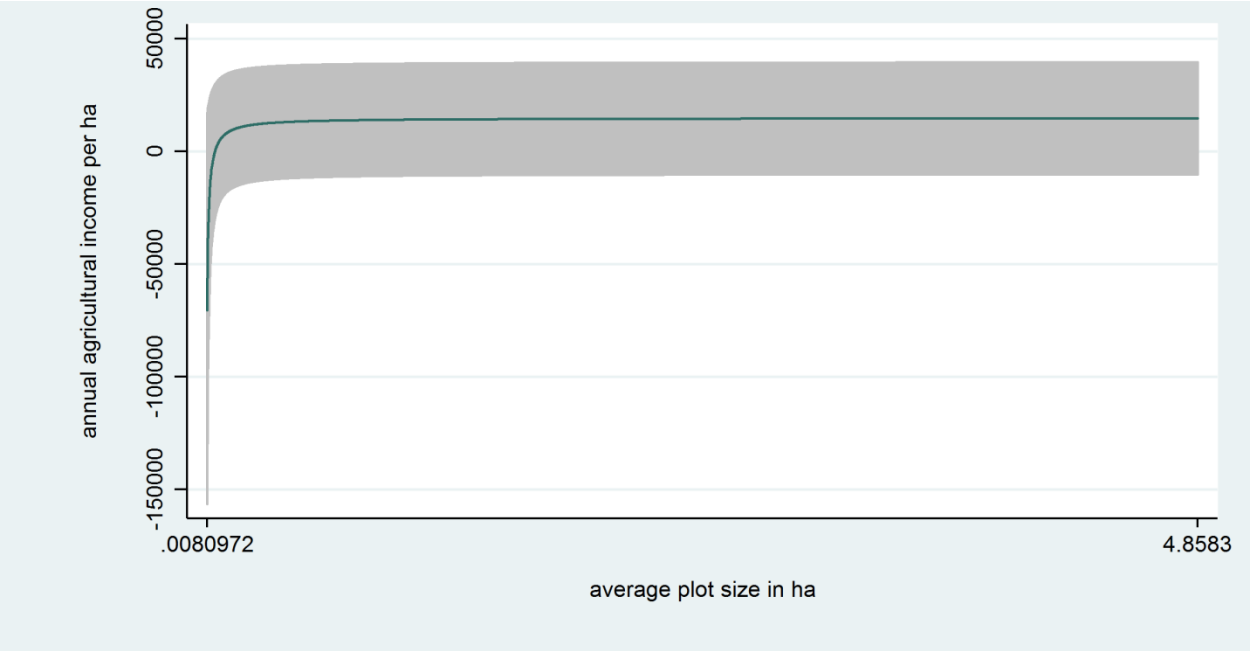


Appendix 1: Fixed-Effects models describing the productivity of households between 2010 and 2015; all monetary values in constant prices; standard errors in parentheses; *p<0.05, **p<0.01, ***p<0.001; source: own calculations

	Model A1 HH income from cultivation per ha in INR	Model A2 HH income from all agricultural activities per ha in INR
Average plot size^{-2}	-33.60*** (8.950)	-27.12* (10.61)
Ln of operated area in ha	-12624* (6217)	-29053** (9133)
Income diversity	-17800** (5782)	34.54 (10843)
Ratio of cash crops in total cropping area	7900.5 (5962.4)	14399 (7471)
Work hours per hectare	15.14*** (2.330)	8.789* (3.780)
Annual rainfall in mm	9.851*** (2.153)	11.46** (3.935)
Per capita NSDP in INR	0.0929 (0.0552)	0.186* (0.0844)
Constant	17051*** (4504)	19992** (6783)
Observations	3927	3884
No. of household observations	1071	1068

Appendix 2: Non-linear function of average plot size in Model 1;

transformation: $\frac{1}{\text{average plot size}}$; source: authors



Appendix 3: Non-linear function of operated area in Model 1;
transformation: logarithm of operated area; source: authors