Geography vs. Institutions at the Village Level*

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Abstract — There is well-known debate about the respective roles of geography versus institutions in explaining the long-term development of countries. These debates have usually been based on cross-country regressions where questions about parameter heterogeneity, unobserved heterogeneity, and endogeneity cannot easily be controlled for. The innovation of Acemoglu, Johnson and Robinson (2001) was to address this last point by using settler mortality as an instrument for endogenous institutions and found that this supported their line of reasoning. We believe there is value-added to consider this debate at the micro level within a country as particularly questions of parameter heterogeneity and unobserved heterogeneity are likely to be smaller than between countries. Hence, we examine the determinants of agricultural growth across villages on the Indonesian Island of Sulawesi and find technology adoption to play a crucial role. We show that geography through its effects on migration and institutions is a valid instrument to establish the causal links between institutions and technology adoption as well as technology and agricultural growth.

Key words: Geography, land rights, migration, technology adoption, agricultural development, Indonesia.

***JEL*-Codes:** K11, O12, Q12.

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1. Introduction

The majority of the world's poor resides in rural areas and derives a significant share of their incomes from agriculture. As has been demonstrated empirically many times in the literature, sustainable poverty reduction in rural areas requires improvements in agricultural productivity (e.g. Datt and Ravallion, 1996; 2002; Byerlee, Diao and Jackson, 2005; Ravallion and Chen, 2007; Grimm, Klasen and McKay, 2007; Thurlow and Wobst, 2007). Key to such agricultural productivity improvements are improvements in agricultural production technologies. Thus the critical question arises what are the key drivers of technological change in agriculture. This is of particular relevance in regions where land is still available for conversion to agricultural use, as these are typically the areas where individual property rights are absent or not well defined which might constrain investments in land improvement and new technologies (Besley, 1995; Binswanger, Deininger, and Feder 1995). This situation applies to much of Sub-Saharan Africa, but also significant portions of Latin America and Asia where lowland savannahs and forested areas continue to represent an internal land frontier that is being converted to agricultural uses.

When studying the literature on determinants of agricultural productivity growth, several seemingly competing hypotheses are invoked. A first strand of the literature argues that geography is the dominant factor in determining agricultural productivity, such as climate, topography and soil quality of the cultivated land area (see e.g. Diamond, 1997; Gallup, Sachs and Mellinger, 1998). A second strand of the literature emphasizes population size and density, and associated pressure on land, inducing technological improvements or the adoption of new existing technologies (see e.g. Boserup 1981; Kremer, 1993; Klasen and Nestmann, 2005). A third strand of the literature puts emphasizes the role of endogenous institutional change as critical for improvements in agriculture (North, 1987; Hayami and Ruttan, 1985). Within that literature, the role of land rights has received particular emphasis (e.g. Besley, 1995; Rozelle and Li, 1998). Land rights would provide security to the land owner and constitute a collateral, so the argument. Both in turn would have a positive impact on investment in new and more productive technologies. This literature also suggests that land rights are endogenous, responding, among others, to past investment decisions in the land, land scarcity, land quality, as well as the differential power of different rural groups (e.g. Besley, 1995; Binswanger, Deininger, and Feder, 1995; Rozelle and Li, 1998).

These three strands of the literature have evolved quite independently and there are only few studies that explicitly test the relative importance or the inter-relationships between these competing hypotheses.

In this paper, we suggest a theoretical argument which links these three potential explanations and then proceed to test these linkages empirically. We argue that migration to a land frontier is driven by a favorable geography, and that high migration in turn creates land pressure (and possibly also conflict) in these areas. Land pressure induces communities to opt for land rights, which in turn increase the incentive of farmers to invest in agricultural technology. Eventually, agricultural technology enhances agricultural growth and economic development. In short, geography-induced institutional change is the core element of our argument.

In this sense, it is a "micro version" of the well-known "*Institutions Hypothesis*", which tries to explain long run differences in economic development across countries by lasting differences in the quality of endogenously generated institutions. Acemoglu, Johnson and Robinson (2001), who are some of the principal advocates of this hypothesis, argue that Europeans adopted very different colonization policies in different colonies, resulting in different institutions. In places where Europeans faced high mortality rates (i.e. unfavorable geographic conditions), they could not settle and were more likely to set up extractive institutions. In places where they faced relatively low mortality rates, they settled and set up institutions favorable for individual entrepreneurship. These institutions persisted to the present, so the argument, and explain to a large extent differences in economic development across countries.

To test and illustrate our micro version of that theory, we use an original village level data set, which was collected in 2001 in 80 villages situated close to or in the Lore Lindu National Park on the Indonesian Island of Sulawesi, where land at the rainforest margin has been progressively converted to agricultural land. The reminder of our paper is organized as follows. In the next section, we develop our theoretical argument. In Section three we present our data and lay out our estimation strategy. In Section four we present our results and provide many robustness tests. In Section five we draw some policy implications and conclude.

2. A micro version of the "Institutions Hypothesis"

There is well-known debate about the respective roles of geography versus institutions in explaining the long-term development of countries. While some (e.g. Sachs, 2003: Gallup *et al*., 1998) argue that geographic factors, such as location in the tropics, being land-locked and distant from markets, or being susceptible to particular diseases have a direct impact on reducing the economic potential or regions, the opposing view is that institutions are much more important determinants of long-term economic progress (e.g. Rodrik, Subramanian and Trebbi, 2002; Hall and Jones, 1999). Those in the latter camp allow, however, for the fact that institutions have evolved endogenously responding to, among other things, geographic conditions. This is done most explicitly in Acemoglu *et al.* (2001) where geographic conditions, particularly a high disease burden, affected European settlement patterns which in turn led to extractive institutions in non-settler economies and development-friendly institutions in settler economies. Through historical persistence, these institutions still heavily influence the economic fate of nations today.

These debates have usually been based on cross-country regressions where questions about parameter heterogeneity, unobserved heterogeneity, and endogeneity cannot easily be controlled for. The innovation of Acemoglu *et al.* (2001) was to address this last point by using settler mortality rates as an instrument for endogenous institutions and found that this supported their line of reasoning.

We believe there is value-added to consider this debate at the micro level within a country as particularly questions of parameter heterogeneity and unobserved heterogeneity are likely to be smaller than between countries. If one additionally is able to address the issue of endogeneity by following the empirical methodology suggested by Acemoglu *et al* (2001), we argue that we are able to shed new light on these debates by studying these issues at the micro scale where villages (rather than countries) are our units of observation.

As we are dealing with a rural sample, agricultural growth is the critical driver of overall growth. Agricultural technology adoption is, in turn, widely seen as a major determinant of agricultural growth. In Indonesia for instance a growth accounting exercise shows that over the period 1980 to 1998 11% of the agricultural growth can be attributed to the expansion of irrigated land, 20% to the increase in fertilizer use and 10% to the accumulation of capital

(Mundlak, Larson and Butzer, 2002). However, the question remains how technology adoption arises and how it can be fostered. We argue that institutions more generally, and land rights in particular, as well as geography play a crucial role. In other words, we link the interplay between geography and institutions to economic development. More precisely, we argue that migration to our region at the rainforest margin is induced by a favorable geography. High in-migration in turn creates land pressure (and possibly conflict). Land pressure induces communities to opt for land rights, which in turn increase the incentive to invest in agricultural technology. Eventually, agricultural technology enhances agricultural growth and economic development. In what follows, we discuss each element of that causality chain in more detail.

Obviously, land is immobile and labor is mobile. Hence, in an environment of scarce and regionally unequally distributed land resources labor will move to the localities where land is available and its returns are the highest. Land returns depend on many factors, but geographic features such as the topography, soil quality, rainfall play without doubt a crucial role. For instance fields on steep slopes require much more labor input for the same return than flat fields. They are also much more difficult to irrigate. Hence, it is very likely that in a highly agrarian economy labor moves, all else equal, to localities where the geography is favorable for agriculture.

Increasing population density may lead to tensions on land and under some circumstances even to conflicts providing eventually an incentive for villagers to opt for land management institutions and in particular for land rights reducing the transactions costs in the land market. It may also be an instrument for avoiding further immigration or, in contrast, to attract even more migration by signaling potential migrants that land can be bought. The latter channel may be important when migrants also bring new knowledge and technologies. Obviously "land rights" can take very different forms. Here we mean transfer rights, which may include rights to sell, rent, bequeath, pledge, mortgage and gift. Such rights can either be based on written certificates or on a generally accepted (but not codified) understanding. They can be enforceable in front of a national court or only locally within the village community. They can also be only temporarily if attributed by the village leader and if the latter from time to time takes all land back and reallocates the plots among households.

Irrespective of the exact form of the land rights, it can certainly be argued that land rights affect positively the propensity to investment in agricultural production technologies and capital (e.g. Besley, 1995). This should be the case because land rights provide the household with security, i.e. the probability of expropriation should decrease with the land rights a household enjoys. In other words, the expected returns to investment are higher if land rights exist. Another important consequence of land rights is that they facilitate the collateralization of land. Hence, the bank (or any other lending institution) will charge a lower interest rate. Since farmers tend to equate marginal returns to marginal costs, land rights may increase agricultural investment also by this channel. Finally, land rights reduce the costs of trading land. Hence, land rights allow in case of negative income shocks to cope more easily by selling parts of the land. Besley (1995) finds evidence for all of these channels in rural Ghana, but emphasizes that it is hard to identify the dominating factor. Obviously, the importance of the channels may in turn depend heavily on the exact design of the land rights.

In what follows, we test and illustrate this causality chain empirically using village level data for Central Sulawesi. Our results provide strong evidence for our arguments.[1] Another way to

[1] That, of course, does not preclude that other transmission mechanisms might also be relevant. But the empirical results are fully consistent with the argument we advance here.

express our results is to couch them, similar to Acemoglu *et al.* (2001) in econometric terms. In this sense, technology adoption is endogenous to economic development and that geography through its effects on migration and institutions is a valid instrument to establish the causal link between technology and agricultural growth.

3. Data and estimation strategy

3.1. Data

To test and illustrate our argument we use a village survey which was conducted during March to July in 2001 in the Lore Lindu region. This region includes the Lore Lindu National Park and the five surrounding sub-districts. It is situated south of Palu, the provincial capital of Central Sulawesi. The survey is part of an international and interdisciplinary research program known as "Stability of Rain Forest Margins" (STORMA) which studies the unique biodiversity of this region and how it can be protected. For the survey 80 of the 119 villages in the region were selected using a stratified random sampling method (Zeller, Schwarze and van Rheenen, 2002) The survey collected data on current population, past and current land use, agricultural technologies and technical changes, and infrastructure. Additional information on agricultural technology, population and geographic features was collected from secondary data and added to the data set by Maertens, Zeller and Birner (2006).

The Lore Lindu region is predominantly a rural area. 87% of the 33,000 households living in the region depend economically on agriculture. 15% of the total area—excluding the National Park—is used for agricultural production. The rest of the area is mainly grasslands and forests. The principal food crop is paddy rice. Important cash crops are cocoa and coffee. Households mainly operate as smallholders and with a very few exceptions there are almost no large plantations in the region (see Maertens *et al.*, 2006).

3.2. Estimation strategy

First, we show that agricultural technology is an important or even the dominant driver of growth. We estimate using ordinary least-squares (OLS) the following equation:

$$\dot{Y}_i = \mu + A_i^{'}\alpha + X_i^{'}\gamma + \varepsilon_i , \qquad (1)$$

where the index *i* stands for the villages. Since the survey does not provide any information on income or income growth on the village level, we use the percentage of all houses in each village built from stone, bricks or cement. Throughout the Lore Lindu region having a stone house is seen as sign of prosperity and wealth and therefore that variable should be a good measure of the villager's long term living standard, *Y*. Moreover, that information is available not only for 2001, but also for 1995, 1990 and 1980 allowing to measure growth in living standards over time—possibly even much better as retrospective information on income would allow to do. Growth in average prosperity of the community is then measured as the average yearly difference in the percentage of stone houses ($\dot{Y}$).[2] As measures of agricultural technology (*A*) we use the existence of technical or semi-technical irrigation systems as well as the use of fertilizer, pesticides, and improved seeds. This information is also available for 1980, 1990, 1995 and 2001. The vector *X* stands for additional control variables such as land inequality, initial population size, initial education and ethnical diversity. If we derived this equation from a Solow-type growth model and used this equation to estimate the transition

[2] We use the difference in shares and not in absolute numbers to avoid that the variable is biased by population growth.

path to the steady state, we would need to include initial income to control for conditional convergence. If we derived the equation from a simple endogenous growth framework, we would not expect such convergence to hold (see below and Barro and Sala-i-Martin, 2004).

To identify the drivers of technology adoption and to avoid any possible problems stemming from reverse causality, omitted variable bias and measurement error in Equation (1), we estimate then, in line with our arguments made in the previous section, the following set of equations using OLS in each time.

$$M_i = \lambda_I + G_i^{'}\beta_I + X_i^{'}\gamma_I + \upsilon_{Ii}, \quad (2)$$

$$R_i = \lambda_R + \beta_R M_i + X_i^{'}\gamma_R + \upsilon_{Ri}, \quad (3)$$

$$A_i = \lambda_A + \beta_A R_i + X_i^{'}\gamma_A + \upsilon_{Ai} \quad (4)$$

Equation (2) estimates the effect of geography (G) on immigration (M). As a measure of the geographic features of the villages we use the share of agricultural land which is on steep slopes, the year of the last drought as a measure of the frequency of droughts and whether the village is accessible by car. Immigration is measured as the difference of immigrating and emigration households over a given period divided by the number of households in the village at the beginning of that period.

Equation (3) estimates the effect of immigration on the existence of land rights (R). Land rights are measured by a dummy variable, which takes the value one if in village *i* people have legal government titles for agricultural land. As it is the case of most of the variables we use, this information is again available not only for 2001 but also retrospectively for 1980, 1990, 1995 and 2001, which will allow avoiding any endogeneity problems.

The last Equation above (4) estimates the effect of land rights on technology adoption (A). Again, as measures of agricultural technology (*A*) we use the existence of technical or semi-technical irrigation systems as well as the use of fertilizer, pesticides, and improved seeds.

After having provided evidence for each transmission channel from geography via immigration and land rights to technology and eventually to growth, following the empirical strategy of Acemoglu *et al.* (2001), we then use instrumental variables estimation techniques to show that geography-induced changes in land rights and thus technology drive rural development. Hence, we estimate in two steps the following equations

$$A_i = \pi_A + G_i^{'}\pi_A + \omega_{Ai}, \quad (5)$$

$$\dot{Y}_i = \mu + \hat{A}_i^{'}\alpha + X_i^{'}\gamma + \varepsilon_i \quad \text{with} \quad \hat{A}_i = \hat{\pi}_A + G_i^{'}\hat{\pi}_A. \quad (6)$$

To check the robustness of our results, we provide various robustness tests and perform the necessary over-identification tests to show the reasonableness of our exclusion restriction.

Table 1 presents some descriptive statistics of the variables we use in our analysis. As the table shows all our time-varying variables such as technology, institutions, and population show a reasonable variation not only across villages but also over time, which should facilitate the identification of the various transmission channels using appropriate time lags.

[Please insert Table 1]

4. Results

4.1. Technology and economic development: OLS results

Table 2 reports OLS regressions of Equation (1), i.e. of growth of the percentage of houses built from stone, bricks or cement on various measures of agricultural technology as well as additional control variables.

[Please insert Table 2]

Columns (1)–(4) show that all technology variables have a positive and highly significant impact on economic performance. The highest explanatory powers are in the regressions using the existence of technical or semi-technical irrigation systems and the use of fertilizer. Note that technology is measured in 1995 and growth over the period 1995 to 2001, i.e. reverse causality should not be an issue here, but in any case IV techniques will be used below. If all variables are used together (column (5)), only irrigation and fertilizer use come out as significant. This is mainly due to the fact, that the use of fertilizer, pesticides and improved seeds are strongly correlated and thus measure similar things. Among the control variables only initial population size and the number of ethnic groups in the village have a significant impact (column (6)). Both enter with a positive sign. The number of ethnic groups might be endogenous. However, we tested that possibility by regressing the number of ethnic groups on the net migration rate and found no significant impact. Land inequality as measured by the Gini coefficient over those households possessing land has no significant impact (this is also the case if the Gini coefficient over *all* households is used). The existence of a primary school in 1980, which we use as a proxy of adult's or initial education, has also no significant impact. We also included the initial share of stone houses to capture a 'conditional convergence' effect. When including it in regressions (1)-(4), the effect is always positive and sometimes significant, suggesting divergence in this very simple model formulation. In regressions (5)-(8) were fuller models are tested it is always highly insignificant (and usually positive), suggesting no evidence whatsoever for conditional convergence.[3]

Columns (7) and (8) use alternative time spans without any significant change regarding the impact of technology, except in column (8), where we look at growth over the entire period 1980 to 2001. Here only the irrigation system variable comes out as significant.

4.1. The transmission channel from geography to technological change

Table 3 reports OLS regressions of the transmission channel from geography on the net migration rate over the period 1980-90 (cf. Equation (2)). All three measures, the share of agricultural land on steep slopes, the number of years since the last drought and an indicator variable for accessibility by car in 1980 have all the expected signs (columns (1)-(3)). They are all significant at least at the 10% level, except the drought variable which is only significant at 22%. The highest explanatory power has accessibility by car. If all three variables are put together in the regression, the slope variable dominates (column (4)). The

[3] The adjusted R-squared of these models is usually worse than before so that we decided not to show the results here; they are available on request.

results do not change if additional control variables are included in the regression (column (5)). Among them only land inequality has a significant impact. Higher land inequality is associated with higher net immigration. Note that inequality describes the distribution in 2001. Retrospective information is not available for that variable, and hence the direction of causality is not clear here. In sum, Table 3 clearly supports our hypothesis that favorable geography attracts immigration and reduces emigration, thus spurring net migration.

[Please insert Table 3]

Table 4 reports OLS regressions of the transmission channel from net migration on land rights as specified in Equation (3). Migration is still measured over the period 1980-90. The land rights variable takes the value one if in village *i* people had legal government titles for agricultural land in 1990. Column (1) shows that migration has a positive and highly significant impact on the probability of people having land titles. This effect holds if additional control variables are included. Thus, it seems likely that immigration (and induced population pressure) creates an incentive for people to opt for land rights. This process might be accompanied by conflict between native households in the village and migrants or between migrants and the government or another public institution. Unfortunately, the data set we have has only discrete information on such events, i.e. whether such conflicts occurred. It turned out that almost each village has known such conflicts (65 out of 80 villages had land conflicts the past five years) and hence, we would need data on the intensity of those conflicts to consider them appropriately in our causality chain.

[Please insert Table 4]

Table 5 reports OLS regressions of the transmission channel from land rights to agricultural technology. This regression corresponds to Equation (4) above. Land rights reflect the status in 1990 and technology use concerns the year 1995. Columns (1) – (4) show that land rights have a significant and positive impact on each of the four technology variables. These effects also hold if additional controls are included (columns (5)-(6)) and if we take into account the possible endogeneity of land rights (columns (7)-(8)). Thus, land rights create investment incentives and, hence, spur technology adoption.

[Please insert Table 5]

4.3. Technology and economic development: 2SLS results

The results reported in Tables 3 to 5 provide clear support for our hypothesis that geography determines via migration, population pressure and the creation of land rights agricultural technology adoption. Now, we will show that geography-induced technology determines economic performance, which is the last element of our causal chain. Table 6 shows two-stage least square regressions (2SLS) of growth on geography-induced technology adoption as specified in Equations (5) and (6). Columns (1)-(2) report the results of growth on the (lagged) existence of a technical or semi-technical irrigation system, which is instrumented by the drought, slope and accessible by car variables. Growth is measured over two alternative periods. In both regressions instrumented technology has the expected positive sign. Columns (3)-(4) present equivalent results using fertilizer use as technology variable. Hence, the measured effects always show in the expected direction and are all highly significant. In regressions (5) and (6) we include both irrigation and fertilizer as our technology variables. Due to multicollinearity, only fertilizer remains significant, but irrigation access continues to have the right sign and approaches significance, and the regression has the highest explanatory power.[4] *Wu-Hausman-Tests* show that exogeneity of the regressors has only to be rejected for the regressions (1)-(3) and hence IV estimation is required. *Sargan's tests* of overidentification restrictions never reject the validity of our instruments (see Panel C). These results together with the results examining the transmission channels above provide strong empirical support for our hypothesis formulated in Section 2.

The last aspect we have to show is that geography has no direct impact on economic performance i.e. is uncorrelated with the residuals ε_i in Equation (1), but acts only through the hypothesized transmission channel.

[Please insert Table 6]

4.4. Specification Tests

To provide support for the exclusion restriction implied by our approach, Table 7 reports 2SLS regressions of our economic performance variable on technology. We use alternative geographic instruments for technology and add another geographic variable as exogenous regressor. If geography had a direct effect on economic performance, we would expect this variable to come out as significant. We also test whether the 2SLS technology coefficients reported in Part A estimated with the instruments indicated in Part B are significantly different from the technology coefficient shown in Part C, where no additional geography variable is introduced in the model. The test statistics in Part D show that for all possible combinations of instruments and exogenous regressors our exclusion restriction cannot be rejected. However, for the cases where irrigation or fertilizer use are instrumented with the drought and slope variables and accessibility by car is used as exogenous variable (columns (3) and(6)) our exclusion restriction is weak. We assume that the main raison is that fertilizer use and access by car in 1980 are strongly correlated ($\rho=0.63$) and, hence, access by car takes the effect from fertilizer use here. If that is the case, it does not put our results into question.

[Please insert Table 7]

5. Conclusion

We presented evidence for the impact of agricultural technology such as irrigation and the use of fertilizer, pesticides and improved seeds on agricultural growth. This result may not surprise but in contrast to many previous studies our empirical analysis is robust to a likely endogeneity bias of agricultural technology and, more importantly, we show in detail at least one important channel which drives technology adoption. Our results suggest that a favorable geography, such as easily cultivable land and a low frequency of droughts attract migration, which in turn creates land pressure. This provides an incentive for villagers and village leaders to opt for land rights which in turn provide an incentive to invest in agricultural technology. Given that we use geography induced institutions, similar to the more macroeconomic literature on institutions and growth (see Acemoglu *et al.* 2001) our results are also robust to the possible endogeneity of institutions. Institutions could be endogenous in our case, if farmers try to enforce land rights by investing on a piece of land.

Our study implies that assisting villages and village leaders to establish land rights can foster economic development also in areas which are geographically less favored and thus benefit

[4] Since a ‚conditional convergence' term was insignificant in all regressions, it is omitted here.

not from “geography and migration induced institutions”.[5] Put differently, our study nicely shows that institutions foster technology and thus growth, but that institutions arise endogenously only under specific circumstances. If those are not given, there is room for policy to initiate the process exogenously.

However, it should also be noted that the region analyzed in this paper is a rainforest area; therefore immigration-induced deforestation is a potential problem and calls even in geographically favored villages for alternative ways of enforcing land rights. As suggested by Maertens *et al*. (2006), agricultural intensification leading to improved yields and increased labor requirements can help to stabilize the rainforest margin. As in our model they see an improvement of the road network as an appropriate driver of such intensification. Hence, a positive feed-back loop from externally promoted intensification to improved land rights and further technological changes could both stabilize the rainforest margin and promote growth of incomes of households close to it.

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[5] See also Rozelle and Li (1998) on the role of village leaders in land rights in China.

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Tables

Table 1
Descriptive statistics, 80 villages

		Mean	Std. Dev.
Household's well-being			
Percentage of houses built from stone, bricks or cement			
	1980	5.212	(10.547)
	1990	12.127	(17.720)
	1995	20.873	(23.312)
	2001	31.342	(30.287)
Technology adoption			
Semi-technical or technical irrigation system			
	1980	0.188	(0.393)
	1990	0.300	(0.461)
	1995	0.338	(0.476)
	2001	0.475	(0.503)
Use of fertilizer			
	1980	0.400	(0.493)
	1990	0.575	(0.497)
	1995	0.663	(0.476)
	2001	0.738	(0.443)
Use of pesticides			
	1980	0.450	(0.500)
	1990	0.625	(0.487)
	1995	0.763	(0.428)
	2001	0.950	(0.219)
Use of improved seeds			
	1980	0.288	(0.455)
	1990	0.413	(0.495)
	1995	0.563	(0.499)
	2001	0.875	(0.333)
Geography			
Share of agricultural land on steep slopes		0.150	(0.256)
Number of years to last drought		9.150	(10.493)
Village accessible by car			
	1980	0.588	(0.495)
	1990	0.700	(0.461)
	1995	0.738	(0.443)
	2001	0.763	(0.428)
Migration			
Net Migration Rate 1980-1990		0.021	(0.129)
Institutions			
Existing land rights			
	1980	0.088	(0.284)
	1990	0.350	(0.480)
	1995	0.400	(0.493)
	2001	0.625	(0.487)
Additional control variables			
Gini of land inequality		0.347	(0.172)
Population size			
	1980	697.7	(687.7)
	1990	897.6	(815.3)
	1995	998.5	(842.9)
	2001	1116.0	(870.0)
Primary school in village			
	1980	0.850	(0.359)
	1990	0.950	(0.220)
	1995	*missing*	
	2001	0.988	(0.112)
Number of ethnic groups in village		2.613	(2.071)

Source: 2001 STORMA village survey; own computations.

Table 2
The effect of technology adoption on growth, OLS

Dep. Var.	(1) Growth 1995-2001	(2) Growth 1995-2001	(3) Growth 1995-2001	(4) Growth 1995-2001	(5) Growth 1995-2001	(6) Growth 1995-2001	(7) Growth 1990-2001	(8) Growth 1980-2001
Irrigation 1995	2.615***				2.010***	1.656***	0.955***	0.874***
(7): 1990, (8): 1980	(0.441)				(0.436)	(0.459)	(0.323)	(0.310)
Fertilizer 1995		2.404***			1.386**	1.211***	1.602***	0.120
(7): 1990, (8): 1980		(0.456)			(0.581)	(0.599)	(0.481)	(0.365)
Pesticides 1995			1.897***		0.404	0.358	-0.194	0.372
(7): 1990, (8): 1980			(0.549)		(0.583)	(0.584)	(0.470)	(0.3104)
Impr. seeds 1995				1.631***	0.153	0.008	0.357	0.207
(7): 1990, (8): 1980				(0.474)	(0.512)	(0.522)	(0.376)	(0.294)
Land Gini 2001						-0.612	-0.065	1.386**
						(1.211)	(0.848)	(0.571)
Ln pop 1995						0.630*		
(7): 1990, (8): 1980						(0.359)		
Ln pop 1990							0.254	
(7): 1990, (8): 1980							(0.161)	
Ln pop 1980								0.520***
								(0.161)
Prim. school						-0.091	0.054	-0.062
1980						(0.569)	(0.407)	(0.302)
No. ethnic groups						0.174*	0.147*	0.109**
2001						(0.094)	(0.067)	(0.046)
Intercept	1.200***	0.511	0.653	1.165***	0.100	-3.901*	-1.525	-3.166***
	(0.258)	(0.370)	(0.479)	(0.358)	(0.405)	(-1.800)	(0.926)	(0.910)
n	*79*	*79*	*79*	*79*	*79*	*79*	*79*	*77*
Adj. R2	*0.305*	*0.256*	*0.123*	*0.122*	*0.405*	*0.428*	*0.526*	*0.582*

Note: * significant with *p*<10%, ** significant with *p*< 5%, *** significant with *p*<1%. Standard errors in parentheses.
Source: 2001 STORMA village survey; own estimations.

Table 3
The effect of geography on net migration, OLS

Dep. Var.	(1) Net Migr. Rate 1980-1990	(2) Net Migr. Rate 1980-1990	(3) Net Migr. Rate 1980-1990	(4) Net Migr. Rate 1980-1990	(5) Net Migr. Rate 1980-1990
Share of fields	-0.111*			-0.108*	-0.122**
on steep slope	(0.056)			(0.060)	(0.061)
Years to last		0.002		0.002	0.001
drought		(0.001)		(0.001)	(0.001)
Accessible by car			0.053*	0.029	0.019
in 1980			(0.030)	(0.032)	(0.037)
Land Gini 2001					0.197**
					(0.091)
Ln pop 1980					-0.021
					(0.022)
Prim. school					-0.032
1980					(0.046)
No. ethnic groups					0.005
2001					(0.007)
Intercept	0.038**	0.005	-0.011	0.003	0.099
	(0.017)	(0.020)	(0.023)	(0.028)	(0.007)
n	*76*	*76*	*76*	*76*	*76*
Adj. R2	*0.037*	*0.007*	*0.029*	*0.055*	*0.086*

Note: * significant with *p*<10%, ** significant with *p*< 5%, *** significant with *p*<1%. Standard errors in parentheses.
Source: 2001 STORMA village survey; own estimations.

Table 4
The effect of migration on land rights, OLS
(linear probability model)

Dep. Var.	(1) Land rights existing in 1990	(2) Land rights existing in 1990
Net Migr. Rate 1980-1990	0.941**	0.865**
	(0.423)	(0.402)
Land Gini 2001		0.211
		(0.302)
Ln pop 1980		0.282***
		(0.068)
Prim. school 1980		-0.152
		(0.156)
No. ethnic groups 2001		-0.014
		(0.024)
Intercept	0.349**	-1.325***
	(0.055)	(0.416)
n	*76*	*76*
Adj. R2	*0.050*	*0.225*

Note: * significant with *p*<10%, ** significant with *p*< 5%, *** significant with *p*<1%. Standard errors in parentheses.
Source: 2001 STORMA village survey; own estimations.

Table 5
The effect of land rights on technology adoption, OLS and 2SLS
(linear probability model)

Dep. Var.	(1) Irrig. system existing in 1995 (OLS)	(2) Use of fertilizer in 1995 (OLS)	(3) Use of pesticide in 1995 (OLS)	(4) Use of improved seeds in 1995 (OLS)	(5) Irrig. system existing in 1995 (OLS)	(6) Use of fertilizer in 1995 (OLS)	(7) Irrig. system existing in 1995 (2SLS)	(8) Use of fertilizer in 1995 (2SLS)
Land rights existing in 1990 [a]	0.415***	0.354***	0.310***	0.234**	0.255**	0.204*	1.451*	1.981**
	(0.102)	(0.104)	(0.094)	(0.115)	(0.114)	(0.113)	(0.742)	(0.975)
Land Gini 2001					0.165	0.629**	-0.303	-0.066
					(0.292)	(0.290)	(0.545)	(0.716)
Ln pop 1980					0.203***	0.182**	-0.120	-0.297
					(0.074)	(0.074)	(0.227)	(0.298)
Prim. school 1980					-0.055	-0.077	0.184	0.278
					(0.156)	(0.154)	(0.287)	(0.377)
No. ethnic groups 2001					0.026	0.009	0.037	0.026
					(0.023)	(0.023)	(0.038)	(0.050)
Intercept	0.192***	0.538***	0.654***	0.481***	-1.091	-0.745*	0.423	1.505
	(0.060)	(0.062)	(0.056)	(0.068)	(0.437)	(0.433)	(1.146)	(1.506)
n	*80*	*80*	*80*	*80*	*77*	*79*	*77*	*77*
Adj. R2	*0.165*	*0.117*	*0.110*	*0.039*	*0.219*	*0.230*	-	-

Note: * significant with *p*<10%, ** significant with *p*< 5%, *** significant with *p*<1%. Standard errors in parentheses. [a] In columns (7) and (8) land rights are instrumented using the three geographic variables as instruments.
Source: 2001 STORMA village survey; own estimations.

Table 6
The effect of technology adoption on growth, 2SLS

Dep. Var.	(1) Growth 1995-2001	(2) Growth 1990-2001	(3) Growth 1995-2001	(4) Growth 1990-2001	(5) Growth 1995-2001	(6) Growth 1990-2001
PanelA: Second Stage Least Squares						
Irrig. system	4.822***				1.042	
existing in 1995	(1.581)				(2.206)	
Irrig. system		3.714***				1.146
existing in 1990		(1.372)				(1.440)
Use of fertilizer			3.674***		3.104**	
in 1995			(0.925)		(1.479)	
Use of fertilizer				2.335***		1.855**
in 1990				(0.536)		(0.792)
Land Gini 2001	-0.588	0.172	-1.917	-0.387	-1.788	-0.370
	(1.561)	(1.202)	(1.467)	(0.888)	(1.380)	(0.850)
Ln pop 1980	0.183	0.553	0.621	0.559**	0.473	0.478*
	(0.554)	(0.393)	(0.376)	(0.260)	(0.467)	(0.269)
Prim. school	-0.323	0.094	-0.404	-0.085	-0.350	-0.003
1980	(0.694)	(0.633)	(0.707)	(0.439)	(0.659)	(0.433)-
No. ethnic groups	0.092	0.076	0.177*	0.154**	0.157	0.133*
2001	(0.127)	(0.094)	(0.106)	(0.066)	(0.106))	(0.069)
Intercept	-0.459	-3.195	-3.590*	-3.262**	-2.690	-2.856
	(3.097)	(2.158)	(2.087)	(1.446)	(2.710))	(1.475)
n	*77*	*77*	*77*	*77*	*77*	*77*
Adj. R2	*0.028*	*0.034*	*0.260*	*0.512*	*0.370*	*0.553*
Panel B: First Stage for Technology Adoption						
Share of fields	-0.186	-0.256	0.039	0.134	*see col.*	*see col.*
on steep slope	(0.198)	(0.199)	(0.173)	(0.163)	*(1) and (3)*	*(2) and (4)*
Years to last	0.010**	0.008	0.005	0.004	*see col.*	*see col.*
drought	(0.005)	(0.005)	(0.004)	(0.004)	*(1) and (3)*	*(2) and (4)*
Accessible by car	0.349***	0.287***	0.597***	0.721***	*see col.*	*see col.*
in 1980	(0.088)	(0.104)	(0.090)	(0.085)	*(1) and (3)*	*(2) and (4)*
R2	*0.238*	*0.184*	*0.417*	*0.528*		
Panel C: Endogeneity and Overidentification Tests						
Wu-Hausman Test, H0: Regressors exogenous (p-values)	*0.009*	*0.008*	*0.007*	*0.113*	*0.113*	*0.378*
Sargan's test of overidentifying restrictions, H0 excluded instruments are valid (p-values)	*0.183*	*0.236*	*0.739*	*0.637*	*0.491*	*0.583*

Note: * significant with *p*<10%, ** significant with *p*< 5%, *** significant with *p*<1%. Standard errors in parentheses.
Source: 2001 STORMA village survey; own estimations.

Table 7
Specification Tests

Dep. Var.	(1) Growth 1995-2001	(2) Growth 1995-2001	(3) Growth 1995-2001	(4) Growth 1995-2001	(5) Growth 1995-2001	(6) Growth 1995-2001
Part A: *Second Stage Least Squares*						
Irrigation 1995	4.755***	6.968**	1.817			
	(1.646)	(2.727)	(1.641)			
Fertilizer 1995				3.536***	3.689***	2.452
				0.892	(0.946)	(3.671)
Share of fields	-0.105			-0.657		
on steep slope	(1.047)			0.846		
Years to last		-0.047			-0.001	
drought		(0.043)			(0.022)	
Accessible by car			1.565**			0.712
in 1980			(0.626)			(2.088)
n	*77*	*77*	*77*			
Part B: First Stage for Technology Adoption						
Share of fields		-0.086	-0.389*		0.084	-0.306
on steep slope		.197	(0.201)		(0.168)	(0.206
Years to last	0.009*		0.014***	0.005		0.011**
drought	(0.005)		(0.005)	(0.004)		(0.005)
Accessible by car	0.379***	0.408***		0.590***	0.623***	
in 1980	(0.098)	.102		(0.086)	(0.087)	
Part C: Second Stage Least Squares without additional geography variable						
Irrigation 1995	5.134***	7.120***	3.311**			
	(1.662)	(2.670)	(1.489)			
Fertilizer 1995				3.724***	3.655***	4.538**
				(0.894)	(0.902)	(2.278)
Part D: Coefficients in Part A significantly different from coefficients in Part C						
χ^2-Test, H0: coefficients not significantly different (p-values)	*0.818*	*0.955*	*0.316*	*0.833*	*0.709*	*0.360*

Note: * significant with *p*<10%, ** significant with *p*< 5%, *** significant with *p*<1%. Standard errors in parentheses. All regressions include the same control variables as above: Gini coefficient of land inequality, the logarithm of population size in 1980, the existence of a primary school in 1980 and the number of ethnic groups in the village.
Source: 2001 STORMA village survey; own estimations.