Geography vs. Institutions at the Village Level*

Michael Grimm
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and

Stephan Klasen
University of Göttingen

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Abstract — There is a 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 economic development across villages on the Indonesian Island of Sulawesi and find technology adoption to play a crucial role. We show that geography-induced migration together with population size foster through their effect on institutions technology adoption.

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 income growth and 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 available for 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, 2006). A third strand of the literature 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; Deininger, 2003; Rozelle and Li, 1998). According to this argument, land rights would provide security to the land owner and constitute collateral for credit. Both in turn would have a positive impact on investment in new and more productive technologies.[1] 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, our argument is a "micro version" of the well-known "*Institutions Hypothesis*", which tries to explain long run differences in economic development across countries by

[1] Deiniger (2003, Chapter 2) provides empirical evidence from around the developing world for this hypothesis.

lasting differences in the quality of endogenously generated institutions. Acemoglu, Johnson and Robinson (2001), who are some of the principal advocates of this hypothesis, use this argument to explain the differential economic performance of countries. They argue that Europeans adopted very different colonization policies in different colonies, resulting in different institutions across the developing world. 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. Although, the villages we analyze share many common features and are spread over a relatively limited area, they also differ significantly with respect to their level of well-being, geography, technology and institutions. Some of these villages seem to be caught in sort of poverty trap, while others developed fast in the past twenty years. Our analysis will reveal at least one explanation why this was the case.

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 setting, agricultural growth is the critical driver of overall economic 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). All these components involve technology adoption. However, the question remains how technology adoption arises and how it can be fostered. We argue that institutions more generally, and geography-induced land rights in particular play a crucial role. In other words, we link the interplay between geography and institutions to economic development. Table 1 shows that economic growth measured (as will be outlined below) through the percentage change in the share of houses built from stone is significantly higher in villages where geography is more favorable, measured alternatively through the frequency of droughts, the share of agricultural land on steep slopes and the accessibility by car in 1980. Our theory is that this reflects the effect of geography working through migration, land rights and technology adoption. 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. Later we substantiate this by regressing income growth on technology and instrument the latter by geography. But first, we discuss each element of that causal chain in more detail.

[Please insert Table 1]

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. “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 and/or make credit available in the first place if such collateral is provided. Since farmers tend to equate marginal returns to marginal costs, land rights may increase agricultural investment also by this channel. Note that this is not only a valid argument for long term investments, such as an irrigation system, but also for the use of fertilizer, pesticides and improved seeds, given that these inputs can often only be bought if credit is available in the pre-harvest period. 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 causal chain empirically using village level data for Central Sulawesi. Our results provide strong evidence for our arguments. 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.

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 determinants of biodiversity and land use in this region and to determine how such biodiversity can be protected through appropriate socioeconomic mechanisms. 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 rural. 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 very few exceptions there are almost no large plantations in the region (see Maertens *et al.*, 2006). Logging is either done informally and has then only a marginal importance for the local population or is done formally but then by companies from outside the Lore Lindu Region and has again no impact on local incomes.

During the past decades a significant part of the migration has taken place from the south and middle-west of Sulawesi to the north-east, in particular to the districts of Palolo, Sigi Biromaru and Lore Utara. A smaller part of the migration has also taken place within sol called ‘transmigration programs’, organized by the government mainly during the 1960s and

1970s. These programs resettled people in particular from the islands Java, Bali and Lombok in Central-Sulawesi. The places were chosen according to factors such as soil fertility and land availability (Faust, Maertens, Weber et al., 2003). Many of these migrants have today returned. In our sample three villages benefited from such migration during the period 1990-2001. None was affected by these programs during the 1980s.

Land rights became more and more widespread over time in the Lore Lindu region. They can have different forms, e.g. be written or only exist verbally, but they always emerged from a village-specific process. Consistent with our theory one can frequently observe that migrants approach village leaders to get for free or to buy some land although land rights are not existent. Village leaders give for free or sell land, but then usually locals claim new land and this leads to a process where land rights are established and a land market emerges. It is important to emphasize that these land rights arise endogenously and are not imposed by some higher state authority on the villagers. In some villages the village leaders centralize land rights, but in most of the villages where land rights exist, these rights are in the hand of individuals villagers. Land rights are frequently used as collateral in the study region.

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 will be shown below, the share of stone houses varies significantly in our data set and therefore should contain enough information about differences in well-being across villages and over time.

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 ethnic diversity. If we derived this equation from a Solow-type growth model and used this equation to estimate the transition 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 (conditional) 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

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

estimate then, in line with our arguments made in the previous section, the following set of equations using OLS in each time.

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

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

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

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 was accessible by car in 1980. This latter variable is not intended to measure infrastructure. It is rather included as a measure of geographical remoteness and as a measure of geographic traits which make the construction of a road more or less easy.[3] One could argue that the share of agriculture land on steep slopes is not relevant as long as the total land size is very large. However, we argue that this variable is a good measure of geography, since we look only at agricultural land. If enough land in the plain were available villagers would not convert land on steep slopes to agricultural land. Immigration is measured as the difference of immigrating and emigrating 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.

To show how the different elements of our causal chain fit together and to account for the possible endogenity of migration with respect to land rights and of land rights with respect to technology we estimate equations (2) to (4) also using a three-stage least-squares (3SLS) estimator, where migration is instrumented by geography and land rights by geography induced migration.

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

$$A_i = \pi_{A0} + G_i^{'}\pi_{A1} + \omega_{Ai}\,, \tag{5}$$

[3] Given the long time lag of this variable and our observation period on economic growth and the significant changes in accessibility over time, this variable should be relatively independent from accessibility by car today.

$$\dot{Y}_i = \mu + \hat{A}_i^{'}\alpha + X_i^{'}\gamma + \varepsilon_i \quad \text{with} \quad \hat{A}_i = \hat{\pi}_{A0} + G_i^{'}\hat{\pi}_{A1}. \qquad (6)$$

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. The exclusion restriction implied by our instrumental variable regression is that, conditional on the controls included in the regression, villages' geographic traits — measured through the frequency of droughts, the share of agricultural land on steep slopes and the accessibility by car in 1980 —have no direct effect on growth today, other than their effect through migration, institutional development and technology adoption. To provide further evidence for the robustness of our results, we also estimate Equations (1) and (6) in levels and log levels and use a Fixed-Effects estimator where the data allows constructing a short panel.

Table 2 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 2]

4. Results

4.1. Technology and economic development: OLS results

Table 3 reports OLS regressions of Equation (1), i.e. of absolute annual changes in 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 3]

Columns (1)–(4) show that all technology variables have a positive and highly significant impact on economic performance. Note that technology is measured in 1995 and growth over the period 1995 to 2001, i.e. thereby reducing the possibility of endogeneity, 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. Often these techniques are even adopted in a sequence, starting with irrigation, followed first by fertilizer, second by pesticides and last by improved seeds. In our estimations the existence of an irrigation system alone explains 31% in the total variance in growth rates. If additional controls are included (columns (6)) the regression explains 42% of the total variance in growth. The regressions imply that the existence of a technical or semi-technical irrigation system in a village increases the subsequent annual change in the share of stone houses by 1.5 percentage points. 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 educational achievement also has 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) where fuller models are tested it is always highly insignificant (and usually positive), suggesting no evidence whatsoever for conditional convergence.[4] Columns (7) and (8) use alternative time spans without any significant change regarding the impact of technology, except that the coefficient of irrigation is slightly reduced. The R^2 in column (8), where we look at growth over the entire period 1980 to 2001, increases to almost 60%. The results also hold if you use levels instead of growth rates as dependent variable and if we estimate the model using a fixed-effect estimator over the periods 1980, 1990, 1995 and 2001 (detailed results not presented here).

4.2. The transmission channel from geography to technological change

Table 4 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, all have the expected signs (columns (1)-(3)). Two of them, the share of agricultural land on steep slopes and the accessibility by car variable are significant at the 10% level. If all three geography variables are used together they explain roughly 10% of the total variance in growth rates. If additional control variables are included the R^2 increases to 17%. If for instance, the share of agricultural land on steep slopes increases by one percentage point, the net migration rate decreases by 0.12 percentage points. Accessibility by car of the village in 1980 increases the net migration rate in the subsequent period by roughly 2 to 5 percentage points. Among the control variables 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. The literature sometimes suggests that higher land inequality is associated with higher out migration (and thus lower net in-migration). Note that during the period 1980-90 none of the villages was affected by a transmigration program, hence there cannot be a bias arising from this side. In sum, Table 3 clearly supports our hypothesis that favorable geography attracts immigration and reduces emigration, thus spurring net migration. However, the regressions also show that there should be other determinants of net migration as well.

[Please insert Table 4]

Table 5 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. An increase of the net migration rate by ten percentage point increases the probability of land rights by 9.4%. This effect holds if additional control variables are included. Migration alone explains 6% of the total variance in land rights. If the vector of control variables is included, the R^2 increases to 28%. Not also the strong positive impact of population size. Thus, it seems likely that immigration together with natural population growth (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

[4] The R^2 of these models is usually worse than before so that we decided not to show the results here; they are available on request.

five years) and hence, we would need data on the intensity of those conflicts to consider them appropriately in our causal chain. Here again, it is also possible to estimate our model using a Fixed-effects estimator over the periods 1980, 1990, 1995 and 2001. The coefficient of migration reduces a little bit, but stays positive and highly significant providing further evidence for the suggested transmission channel.

[Please insert Table 5]

Table 6 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 highly significant and positive impact on each of the four technology variables. The existence of land rights alone can explain 18% of the total variance in the availability of irrigation systems. If the vector of control variables is added the R^2 increases to 27%. The coefficient of land rights implies that the existence of land rights increases the probability that the village disposes an irrigation system by almost 26%. Again the effects do hold if a Fixed-effects estimator is used.

[Please insert Table 6]

Table 7 shows the results when we estimate our causal chain with the three-stage least-squares estimator which can deal with the possible endogeneity of migration and land rights in our causal chain. We use the existence of an irrigation system and the use of fertilizer as alternative measures of technology adoption. As geographic variables we use alternatively all three suggested measures or only two of them excluding the accessibility by car variable. Again, all variables of interest, geography, migration and land rights have the expected sign and are highly significant. The effects of migration and land rights vary only slightly with the exact specification of geography.

[Please insert Table 7]

4.3. Technology and economic development: 2SLS results

The results reported in Tables 4 to 7 support our hypothesis that geography determines via migration, population pressure and the creation of land rights the adoption of agricultural technologies. Now, we will show that geography-induced technology determines economic performance, which is the last element in our causal chain. Table 8 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. The coefficient of irrigation in columns (1) and (2) is more than twice as high as the uninstrumented coefficient reported in Table 3. For instance, the coefficient in column (1) implies that having an irrigation system in the village increases economic growth as measured by the absolute change in the share of stone houses by roughly 4 percentage points per year. The share of the explained variance in growth rates by the models in columns (1) and (2) is more than 50 percent. Columns (3) and (4) use fertilizer use as technology variable. Again the coefficient has a positive sign, is highly significant and bigger in magnitude as the effect measured in Table 3. According to the results, fertilizer use increases growth by roughly 2 to 3 percentage points annually. Columns (5) and (6) reestimate the models of columns (1) and (2) but using only the frequency of droughts and the share of agricultural land on steep slopes variables as instruments leaving out the accessibility by car variable. Again the effects of irrigation systems and fertilizer use on growth are positive and highly significant.

Wu-Hausman tests show that the assumption the endogeneity of technology cannot be rejected in the models estimated in columns (1) to (3), and hence IV estimation is indeed required. This is not the case in columns (4) to (6). Sargan's test of overidentifying restrictions shows that the assumption of the exogeneity of our instruments can never be rejected. Moreover, performing *F*-tests and using Stock and Yogo's (2004) critical values we see that our instruments are highly relevant at least in columns (3) and (4). In columns (5) and (6) the *F*-statistic is at the lower bound of the critical values. In columns (1) and (2) the *F*-test points to a weak instrument problem.

All results also hold if instead of the absolute growth of the share of stone houses the share itself or the log share is used. Hence, the results in Table 8 show that geography induced technology is an important driver of economic growth. This result coupled with the results obtained in Section 4.2 provides a consistent picture regarding the effect of geography via migration, land rights and technology to economic growth. We cannot completely rule out a weak instrument problem in some of the models presented in Table 8, but at least the estimations in column (3) and (4) show that in this case geography is not only a valid but also a highly relevant instrument. To further support our argument, we now perform further specification tests and discuss the robustness of our results with respect to various assumptions we made above.

[Please insert Table 8]

4.4. Specification Tests

First we provide some additional support for the exclusion restriction implied by our approach. We show that geography has no direct impact on economic performance, and, hence is uncorrelated with the residuals ε_i in Equation (1), but acts only through the hypothesized transmission channel. Table 9 reports 2SLS regressions of our economic performance variable on technology. We use alternative geography variables as instruments for technology and add another geography 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 of Table 9 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 and 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. Remember that we estimated all models above also without the accessibility by car variable using only the two other geography variables. Our results never changed substantially.

[Please insert Table 9]

One might argue that our accessibility by car variable satisfies not the exclusion restriction because building a stone house needs a road. First note that we look at *changes* in the share of stone houses and not only at the *level* of the share. Note also, that our accessibility by car variable concerns the year 1980 whereas the used growth spells concern the period 1995 to

2001 or 1990 to 2001. During the eighties and nineties many roads have been built (compare Table 2). Hence, accessibility by car in 1980 should be a good proxy of the geographic features of the village area and should be uncorrelated with infrastructure today. The first roads can be traced back to the colonial period and were indeed built where geography made it easy. Roads through rougher areas as for example the road to Barisi in the South-East of the Lore-Lindu region were built after 1980. In our dataset, accessibility by car in 1980 is negatively correlated with our share of agricultural land on steep slopes variable (correlation coefficient: -0.25), this also supports the view that this variable is a good measure of geography. Moreover, stones and bricks are often made or collected in the surroundings of the villages and hence, no road is necessary to bring them. Also, heavy materials including stones are in the Lore Lindu region traditionally and still frequently transported using buffalos, donkeys, horses or motorcycles. Given that labor is very cheap transport time plays no important role. In 2001, among the 15 villages without any stone house, 11 are not accessible by car and 4 are accessible. Conversely, 8 villages among the 19 villages which are not accessible by car, have a significant share of stone houses. Lastly, note again that as demonstrated all our results also hold if we exclude the accessibility by car variables from the set of our geography instruments.

One may also question the exogeneity of our "share of agricultural land on steep slopes" variable. One may argue that economic expansion leads to the conversion of land which is more difficult to cultivate than existing land. We checked this hypothesis by comparing villages where expansion of land was still possible in 1990 and 2001 with villages where expansion was still possible on 1990 but not in 2001. Obviously, in the latter villages (10 villages) conversion has taken place. However, in these villages the share of agricultural land on steep slopes was not significantly different from the share observed in the other villages.

Another objection one might have against our argument is that migration has a direct (and not indirect) link on technology adoption. Such a link could exist if migrants bring new technologies to the villages. For example, there is some evidence that Bugalesian migrants are specialist of cultivating coffee. While we do not deny this link — in fact it is complementary to our approach — we claim that this is not the dominating force. We tested this link also empirically by regression technology adoption on the net migration rate. In these regressions migration never came out as significant.

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. While this result per se is not surprising, our empirical analysis is, in contrast to many previous studies, robust to a likely endogeneity bias of agricultural technology. But even 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 together with natural population growth pressure on land. 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. Land rights facilitate also collateralization of land and provide by this channel access to credit which in turn can be used to buy productivity increasing inputs such as fertilizer, pesticides and improved seeds. 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 tried to enforce land rights by investing on a piece of land.

The channel we identify here is similar to the one emphasized by Boserup (1981), but extends it in the sense, that we show that the effect from population on technology is not direct but acts through its effect on the implementation of land rights, which is endogenous in this process. Hence, we provide a link between Boserupian theory and the theory of institutional change as formulated by North (1987) and Hayami and Ruttan (1985).

Of course one should be very cautious in deriving a theory from an instrument - geography in our case-, but note that our theory is not only based on geography-induced technology, but that we empirically trace our causal chain from technology via land rights and demographics back to geography. Hence, geography is not only instrument but in itself the initial driver of development. But given that geography is fixed it is immune to any endogeneity problem and can also serve as an instrument for our purpose.

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

However, it should be noted that the region analyzed in this paper is a rainforest area; therefore immigration-induced deforestation is a potential environmental 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.

But it should also not be overseen that land rights might not improve the livelihoods of all and, often first of all modify traditional land allocation rules. In our study region, it was reported that some villagers behave myopic when land markets arise. They sell land to migrants to make fast money. The land is usually fallow land, which has been kept, e.g. as reserve for heritage. Later, they recognize their mistake, but there is no more free land available. This process leads in some villages to a marginalization of local inhabitants relative to migrants and also accelerates deforestation (Faust *et al.*, 2003; Weber and Faust, 2006).

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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
Reduced form relationship between economic growth and geography

	Years to last drought		Share of agricultural land on steep slopes		Village accessible by car in 1980	
	Less than 8 years	8 years and more	0.15 and more	Less than 0.15	No	Yes
Annual percentage change in share of houses built from stone, cement or bricks 1995-2001	1.551	2.278	1.071	1.989	0.460	2.667
p-value (H0: difference = 0)	0.183		0.031		0.000	

Table 2
Descriptive statistics, 80 villages

		Mean	Std. Dev.
Household's well-being			
Share of houses built from stone, bricks or cement in the villages			
	1980	0.052	(0.105)
	1990	0.121	(0.177)
	1995	0.209	(0.233)
	2001	0.313	(0.303)
Technology adoption			
Villages with 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)
Villages using fertilizer			
	1980	0.400	(0.493)
	1990	0.575	(0.497)
	1995	0.663	(0.476)
	2001	0.738	(0.443)
Villages using pesticides			
	1980	0.450	(0.500)
	1990	0.625	(0.487)
	1995	0.763	(0.428)
	2001	0.950	(0.219)
Villages using 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 in the villages		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)

		Mean	Std. Dev.
Migration			
Net Migration Rate 1980-1990		0.021	(0.129)
Institutions			
Villages with 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 in 2001		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)
Village with primary school			
	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 3
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 system existing in 1995 (7): 1990, (8): 1980	2.179*** (0.0.367)				1.675*** (0.363)	1.521*** (0.392)	1.414*** (0.348)	1.199*** (0.275)
Use of fertilizer in 1995 (7): 1990, (8): 1980		2.004*** (0.380)			1.155** (0.484)			
Use of pesticides in 1995 (7): 1990, (8): 1980			1.581*** (0.458)		0.337 (0.485)			
Use of impr. seeds in 1995 (7): 1990, (8): 1980				1.360*** (0.395)	0.127 (0.427)			
Land Gini 2001						0.125 (1.001)	1.011 (0.915)	1.731*** (0.550)
Ln pop 1995 (7): 1990, (8): 1980						0.879*** (0.272)	0.592*** (0.164)	0.644*** (0.150)
Prim. school 1980						-0.193 (0.478)	-0.132 (0.455)	-0.155 (0.293)
No. ethnic groups 2001						0.145* (0.080)	0.102 (0.074)	0.084* (0.045)
Intercept	1.000*** (0.215)	0.426 (0.308)	0.544 (0.399)	0.971*** (0.298)	0.084 (0.338)	-4.880*** (1.754)	-2.996*** (0.990)	-3.697*** (0.882)
n	*79*	*79*	*79*	*79*	*79*	*79*	*79*	*77*
R2	*0.314*	*0.265*	*0.134*	*0.133*	*0.435*	0.424	0.427	0.597

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 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 on steep slope	-0.111* (0.056)			-0.108* (0.060)	-0.122** (0.061)
Years to last drought		0.002 (0.001)		0.002 (0.001)	0.001 (0.001)
Accessible by car in 1980			0.053* (0.030)	0.029 (0.032)	0.019 (0.037)
Land Gini 2001					0.197** (0.091)
Ln pop 1980					-0.022 (0.022)
Prim. school 1980					-0.032 (0.046)
No. ethnic groups 2001					0.005 (0.007)
Intercept	0.038** (0.017)	0.005 (0.020)	-0.011 (0.023)	0.003 (0.028)	0.099 (0.007)
n	*76*	*76*	*76*	*76*	*76*
R2	*0.050*	*0.020*	*0.042*	*0.093*	*0.171*

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 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*
R2	*0.063*	*0.277*

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 6
The effect of land rights on technology adoption, OLS
(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)
Land rights existing in 1990	0.415***	0.354***	0.310***	0.234**	0.255**	0.204*
	(0.102)	(0.105)	(0.094)	(0.115)	(0.114)	(0.113)
Land Gini 2001					0.165	0.629**
					(0.292)	(0.290)
Ln pop 1980					0.203***	0.182**
					(0.074)	(0.074)
Prim. school 1980					-0.055	-0.077
					(0.156)	(0.154)
No. ethnic groups 2001					0.026	0.009
					(0.023)	(0.023)
Intercept	0.192***	0.538***	0.654***	0.481***	-1.091	-0.745*
	(0.060)	(0.062)	(0.056)	(0.068)	(0.437)	(0.433)
n	*80*	*80*	*80*	*80*	*77*	*79*
R2	*0.175*	*0.128*	*0.121*	*0.050*	*0.270*	*0.280*

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
The effect of geography via migration and land rights on technology adoption, 3SLS

Dep. Var.	(1) Irrig. system existing in 1995	(2) Irrig. system existing In 1995	(3) Use of fertilizer in 1995	(4) Use of fertilizer in 1995
Irrigation (1) – (2) / Fertilizer (3) – (4)				
Land rights existing in 1990	1.508**	1.532*	2.307***	1.184
	(0.590)	(0.872)	(0.742)	(0.768)
Land Gini 2001	-0.080	0.008	0.281	0.526
	(0.390)	(0.452)	(0.467)	(0.415)
Ln pop 1980	0.091	0.141	-0.073	0.128
	(0.176)	(0.254)	(0.217)	(0.224)
Prim. school 1980	0.066	0.047	0.100	-0.004
	(0.194)	(0.229)	(0.223)	(0.212)
No. ethnic groups 2001	0.025	0.023	0.013	0.004
	(0.027)	(0.029)	(0.031)	(0.027)
Intercept	-0.868	-1.199	0.031	-0.786
	(0.865)	(1.221)	(1.049)	(1.083)
Land rights existing in 1990				
Net Migr. Rate 1980-1990	2.405**	2.260**	2.028**	2.314**
	(0.982	(1.011)	(0.965)	(1.016)
Intercept	0.319***	0.322***	0.327***	0.321***
	(0.059	(0.059)	(0.059)	(0.059)
Net Migr. Rate 1980-1990				
Share of fields on steep slope	-0.081	-0.117**	-0.048	-0.120**
	(0.051)	(0.053)	(0.049)	(0.053)
Years to last drought	0.002*	0.003**	0.001	0.003**
	(0.001)	(0.001)	(0.001)	((0.001)
Accessible by car in 1980	0.055**		0.076***	
	(0.027)		(0.026)	
Intercept	-0.020	0.012	-0.030	0.014
	(0.024)	(0.019)	(0.023)	(0.019)
n	*76*	*76*	*76*	*76*

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

Table 8
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 1995-2001
Second Stage Least Squares						
Irrig. system existing in 1995	4.019***				2.759**	
	(1.266)				(1.241)	
Irrig. system existing in 1990		3.715***				
		(1.372)				
Use of fertilizer in 1995			3.062***			3.782**
			(0.740)			(1.898
Use of fertilizer in 1990				2.335***		
				(0.515)		
Land Gini 2001	-0.490	0.172	-1.597	-0.387	-0.157	-2.108
	(1.249)	(1.154)	(1.173)	(0.852)	(1.078)	(1.769)
Ln pop 1980	0.153	0.553	0.517	0.559**	0.494	0.347
	(0.443)	(0.378)	(0.301)	(0.250)	(0.413)	(0.523)
Prim. school 1980	-0.270	0.094	-0.336	-0.085	-0.403	-0.252
	(0.655)	(0.608)	(0.565)	(0.421)	(0.562)	(0.650)-
No. ethnic groups 2001	0.077	0.076	0.148*	0.154**	0.106	0.143
	(0.102)	(0.094)	(0.085)	(0.064)	(0.088))	(0.094)
Intercept	-0.382	-3.191	-2.992*	-3.262**	-2.163	-2.270
	(2.478)	(2.158)	(1.670)	(1.389)	(2.285))	(2.509)
n	*77*	*77*	*77*	*77*	*77*	*77*
R2	*0.527*	*0.568*	0.640	*0.782*	*0.656*	0.570
First Stage for Technology Adoption						
Years to last drought	0.011**	0.008	0.005	0.004	0.012**	0.009*
	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)
Share of fields on steep slope	-0.216	-0.301	0.074	0.109	-0.332*	-0.244
	(0.202)	(0.210)	(0.176)	(0.158)	(0.193)	(0.194)
Accessible by car in 1980	0.202*	0.165***	0.553***	0.601***		
	(0.121)	(0.126)	(0.105)	(0.000)		
R2	*0.330*	*0.233*	0.495	*0.618*	0.303	0.293
Endogeneity and Overidentification Tests						
Wu-Hausman Test, H0: Regressors exogenous (p-values)	*0.009*	*0.008*	*0.007*	*0.113*	*0.271*	*0.163*
Sargan's test of overidentifying restrictions, H0 excluded instruments are valid (p-values)	*0.183*	*0.236*	*0.739*	*0.637*	*0.514*	*0.566*
Stock and Yogo's F-test for first-stage regression	*3.820*	*2.750*	*11.280*	*15.990*	*4.230*	*2.220*

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 9
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	3.963***	5.807**	1.514			
	(1.372)	(2.273)	(1.367)			
Fertilizer 1995				2.947***	3.074***	2.044
				0.743	(0.788)	(3.511)
Share of fields on steep slope	-0.088			-0.548		
	(0.873)			(0.705)		
Years to last drought		-0.040			-0.001	
		(0.036)			(0.018)	
Accessible by car in 1980			1.305**			0.594
			(0.521)			(2.003)
n	*77*	*77*	*77*	*77*	*77*	*77*
Part B: First Stage for Technology Adoption						
Share of fields on steep slope		-0.216	-0.216		0.074	0.074
		(0.202)	(0.202)		(0.176)	(0.176)
Years to last drought	0.011**		0.011**	0.005		0.005
	(0.005)		(0.005)	(0.004)		(0.004)
Accessible by car in 1980	0.202*	0.202*		0.553***	0.553***	
	(0.121)	(0.121)		(0.105)	(0.105)	
Part C: Second Stage Least Squares without additional geography variable						
Irrigation 1995	4.279***	5.933***	2.759**			
	(1.385)	(2.225)	(1.241)			
Fertilizer 1995				3.103***	3.046***	3.782**
				(0.745)	(0.752)	(1.884)
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*	*0.702*	*0.316*	*0.832*	*0.970*	*0.356*

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.