Labor productivity and natural resources: An assessment at the national level in Honduras.

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Abstract

The study establishes the link between agricultural labor productivity and natural resources variables at the national level in Honduras. We show through spatial analysis of productivity and natural resources that the relationship between natural resource conditions and agricultural productivity is not as direct as one can imagine. Length of the rainy season has a strong and quasi linear relation with income. Soil has little impact on productivity as well as slope and altitude since coffee production in the mountain has a strong relation on productivity. Access to the main cities and to the main seaports has little relation with productivity since some of the main cities are located in unproductive areas. Improving the small road network would have a more positive impact. The study suggests that good research and good policies can have a good impact on productivity.

Introduction

Is there a strong relation between soil, climate, germplasm, pest and labor productivity[1] in an region? One can guess that natural resource conditions will have a strong impact on any society. Aren't temperate countries more developed than tropical countries, mountainous areas less developed than valleys, semi-arid conditions more adverse to agriculture than sub-humid or temperate conditions? However the relation is not as direct as it first looks. For instance temperate countries were at least as poor as tropical countries before the industrial revolution occurred. Mountainous areas of Africa and pre-Colombian Latin America were most productive regions than valleys and lowland. During the middle age semi-arid societies of Africa were much more developed and populated than the sub-humid regions of Africa. The relation between natural resources and productivity clearly exists but can be modified by human societies.

Is it necessary to study in-depth the history of a region before starting a project? It would certainly help planners to know where the area is coming from in terms of farm structure and productivity but in-depth historical studies are not always possible for lack of time and data. Project planners and policy makers usually need a rapid understanding of the main variables explaining the productivity in a region. In this paper we argue that , thanks to the rapid improvement of Geographical Information Systems (GIS) and statistical packages, it becomes possible to do rapid cross sectional analysis of different map layers to improve the understanding of large scale agricultural situation. We argue that this is possible even in developing countries.

We first present the state of the theoretical debate concerning the various variables affecting agricultural productivity. Second, we present the state of the debate in Honduras. Third, we present the applied methodology and the different variables extracted from the different datasets of Honduras. Fourth we present the results of different statistical methods including correlation, linear regression and cluster analysis.

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[1] We used productivity per worker as a proxy for poverty because it is likely that farmers and communities with low productivity encounter more problems of malnutrition and health than more productive ones. Productivity is also more directly linked to natural resource conditions than other indicators of poverty such as access to public services or education. Poverty is a broader concept than productivity and we will not use the term poverty is this study unless we mean the broader concept.

Variables of labor productivity

The main variables of labor productivity are natural resource conditions, population density, access to market, new technologies, extension, land concentration, credit and property right.

Natural resources

Natural resources have an impact on productivity mainly through temperature, rainfall, soil condition, germplasm and pest. There are different notions of ecosystem fertility for different crops. The supposed unfavorable acid soils are favorable for coffee production but adverse for maize and bean production. The supposed favorable flat land can be adverse to crops production if soils are too heavy. Abundant rainfalls can be favorable for crop growth but also favorable to crop pests. Some ecosystems might look favorable for agro-climatologists but then unfavorable for the farmers that live there because they lack capital, knowledge or adequate germplasm. A deep understanding of the identification of the relations between natural resources conditions and productivity require a thorough analysis of geographical and historical variables (Diamond 1998). In addition societies adapt to their environment in different ways. Many poorly endowed regions have a large well nourished population and many well endowed regions have a large mal nourished population. Other variables than natural conditions can explain labor productivity. These variables can mask the initial influence of natural conditions. The most frequently quoted other variables of labor productivity are population density, access to market, technologies, infrastructures, unequal access to resources, access to capital, education, extension and property rights.

Land degradation can be included as a natural resource variable even if the degradation is man made. Processes of erosion, nutrient mining, weed infestation, overgrazing are widespread and can explain the low productivity of a particular area. Conventional wisdom says that degradation occurs mainly in regions where population increases or where access to market improves.

Population density

Population density is still one of the most frequently proposed explanation for low productivity per capita. Neo-Malthusians consider that high population density leads to lower productivity because farms become smaller and production per unit of area hardly compensates for the decreasing size of the farm. Neo-Malthusians consider that many regions have become poor because the population has exceeded the carrying capacity of the region. Boserup (1965) challenged this view postulating that a high population density is likely to lead to higher productivity per worker because intensification can compensate for the decreasing area per worker. The debate is still on-ongoing but there seems to be a consensus today that there might be a U-shaped relation between labor productivity and population density where increasing population density leads to a decreasing labor productivity until a low point where it becomes necessary and possible to adopt technologies and institutions that will reverse the trend (Sherr and Hazell 1994, Templeton and Scherr 1997, Tiffen, Mortimore and Gichuki 1994).

Market access

The debate about population density is increasingly shadowed by the debate about access to market. The argument is not new however since Von Thηnen in 1826 already explained clearly the relation between distance and agricultural productivity. Most economists believe that productivity is likely to increase in areas with improved access to market regardless of population density and natural resources. The reason of that is that with improved access, prices of produced commodities increase while the prices of purchased input and machinery decreases. Many marginal areas become productive because they became connected to large consumption centers. Many potentially productive ecosystem regions are not producing because they are far from a large consumption centers or seaport. However, the argument that access to market increases productivity has been consistently challenged by observations that access to market can increase land concentration and speculative use of land. This concentration benefits to the wealthy at the expense of the poor because better access is likely to lead to increasing land prices. In dual societies like in

Latin America increasing land price tend to lead to land concentration especially if small farmers do not have titles over their land.

Technologies

Regardless of population density, access to market, and natural resources, many professionals working in developing countries argue that productivity increase is first a problem of technological development. A new germplasm, a new cropping pattern, a new machinery, a new pesticide can make a great difference in any region. Maybe the new technology already existed by was not adopted because it was unknown, or not well adapted or too expensive. However there might be some endogenecty in the technological development with farms adopting new technologies only when population or market pressure favor the adoption (Hayami and Ruttan 1990). As well as the variable market, the variable technology is not neutral.

Land concentration

Natural resource, population density, and access to market are not sufficient to explain low productivity. Structural inequalities can strongly affect productivity. Especially in Latin America land speculation leads to lower productivity in well endowed regions with good infrastructures (De Janvry, Sadoulet and Young 1989).

Education

Many donors believe that education should be the priority to boost agricultural productivity. Education supposedly increases the increases the adoption of new technologies and increases environment awareness. However there is little evidences of a positive relation between education and agricultural productivity.

Extension services

Extension services are considered as strong variables of productivity increase. Technology adoption is not always automatic. The green revolution is in part attributed to an dense and aggressive extension service (Lele and Stone 1989).

Credit

Lack of capital is one of the major constraint of productivity. Credit necessarily is not linked to extension services. Access to credit is usually easier in high potential areas while extension services are often redirected toward low potential areas where credit is much more difficult to obtain.

Property right

In recent years property right has become the focus of detailed analysis to try to check if more secure property rights will lead to a better productivity. Many development agencies are now conducting large titling programs based on the assumption that more secure property right and an active land market will improve the allocation of resources (Strasma and Celis. 1992).

The theoretical model

This study aims to identify the importance of some of the variables listed previously in explaining labor productivity in 3,731 villages of Honduras. The theoretical model explaining labor productivity is the following:

$$PW = b1 . NR + b2 . PD + b3 . AC + b4 . TEC + b5 . LC + b6 . ED + b7 . EX + b8 . CR + b9 . PR$$

Where PW is production per worker; NR is natural resource conditions; PD is population density; AC is access to market; TEC is technology; LC is land concentration, ED is education; EX is extension; CR is credit and PR is property right. Discussions about the measurement of each variable and the potential statistical problems of the model is discussed later. We will first review the literature dealing with some of these variables in the context of Honduras.

Agricultural productivity in Honduras

There has been serious effort in Honduras to try to explain agricultural production. The government produced three agricultural censuses of the whole country in 1952, 1974 and 1993 including abundant information about the different productions of each farm of Honduras (DGECH 1952, 1968, 1994). These datasets are considered to be of relatively good quality even if the questionnaire needs some improvement. The censuses used as the base of most analysis of the agricultural sector (Baumeister et al 1996; IICA 1995; Salgado et al. 1994).

According to these data and others concerning the other sectors, the Honduran economy is still largely dependent upon agriculture. Agricultural exports represents 85 percent of Honduran exports including coffee, banana, tropical fruits, shrimp, meat, milk products and wood. Agriculture represents 25 percent of the national GDP but a large fraction of the Agro-food industry depends upon agricultural production. The rural population represents 55 percent of the total population and agriculture employs 33 percent of the manpower (IICA 1995) but the agricultural productivity is low explaining the very low agricultural wages. An estimated 40 percent of the Honduran agricultural manpower is employed in valleys while the 60 percent remaining works in the hillsides. It is considered that 80 percent of Honduras rural population lives bellow poverty level (IICA 1995).

Despite some limitations due to slope Honduras has some natural comparative advantages (Neidecker and Scherr 1995). The climate is relatively favorable with abundant rainfalls and a short dry season in most of the country. Temperature is optimal for almost any kind of productive crop. With modern inputs, crop yields could increase significantly from their current low level. The potential for irrigation is important since a very small fraction of the country's water is used. The main limitation is that eighty five percent of the country is hilly. Mechanization is only possible on a small fraction of the country and access is difficult in most part of the country. However the economic return from hillside activities such as forestry, livestock production, coffee and horticultural production could be improved significantly with better management.

The evolution of productivity over the last three decades has been disappointing. Yields have stagnated at a low level despite a dramatic increase of fertilizers use even among small farmers. More than 34 percent of farmers having less than 3 hectares apply chemical fertilizers suggesting that farmers use fertilizers to compensate for land degradation. This situation is confirmed by case studies (Jansen 1998). The number of landless and quasi landless (less than 1 ha) has increased from 18 percent in 1952 to 44 % in 1993 (Baumeister et al 1996). At the same time the export industry in the valley has declined sharply. Valleys are partially used for intensive export crops but also for extensive livestock and for land speculation (Stonich 1989, Leonard 1987). In Honduras and Central America there is an abundant literature about the problem of land concentration (Brockett 1988, Stonich 1991, Thorpe 1995, Ruben 1989, DeWalt 1985). Most of this literature challenges the idea that low productivity and land degradation in Honduras is a problem of population pressure or natural resource inadequacy.

In the hillside most of the specialization is explained by altitude and road access (Pender et al 1998). For the central region of Honduras, medium altitude, fewer than average days of rainfalls and steep slopes explain that the farming systems tend to specialize into maize. At higher altitude and further from the capital city the farming systems tend to specialize into coffee. At higher altitude but close to cities the farming systems tend to specialize into horticultural. In some forested areas the government managed to foster a forestry specialization. Close to cities communities adopt non farm employment specialization.

Population density has little significance. Land degradation was more likely to occur in the maize specialization. The conclusion of the Pender et al. study seems to be that geography matters and that any development effort has to be targeted on a clear typology of communities.

A few case studies help to understand more deeply the relation between poverty, production and natural resources (Escolan et al 1998, Jansen 1998, Bergeron et al 1999, Stonich 1991, Dvorak et al. 1996). Similarly, land degradation and promotion of land conservation practices have had a large attention in Central America (Lutz, Pagiola and Reiche 1994, Current, Lutz and Scherr 1996, Sims and Ellis-Jones 1994, Valdes 1994). The general consensus is that the degradation is serious in the hillsides, that there are cost effective techniques of conservation but little adoption. Little consensus exists about the many possible reasons of the non adoption.

Methodology

The objective of the study is to identify through a cross-sectional analysis different relations that can help explain the current levels of productivity in the different eco-regions of Honduras. One specificity of this study is that we use the 1993 agricultural census at the farm level, aggregate the results at the village level and overlap the socio-economic variables with environmental and infrastructures variables.

Honduras is a data rich environment (Knapp and al. 1999) thanks to the habit of the government to perform regular censuses of agricultural and population. Similarly national and international organizations have performed numerous studies of the country's biophysical environment. CIAT has produced in collaboration with the Honduran network of GIS a CD-Rom including an Atlas of Honduras with 50 digitized maps related to natural resources, agriculture and infrastructures (Barona et al 1999). We also used a new soil database produced byt CIAT (Tulio and Barreto 1999). There are more than 50 other digitized maps of the country covering a wide range of themes from socio-economic data, infrastructure, soil, climate and land use. These themes can be overlapped to analyze different problems. Thanks to the rapid improvement of micro-computers many of these maps at the country level are now sufficiently detailed to become usable for local level analysis.

Honduras counts four administrative levels with 18 departments, around 298 municipalities, around 3,731 villages and many more hamlets. The 1993 censuses counted 317,000 farms and a rural population of 2.9 millions on 3.3 million hectares. All villages are geo-referenced and can be located into their respective environment within biophysical and infrastructures maps. Most of these maps are at the scale of 50,000 which gives a relatively good approximation of the local edaphic relations.

Three statistical techniques were used to describe the relations between the many variables at hand. First, we calculated different correlation between variables one by one. Second, we performed a multivariate regression to see if productivity can be reasonably predicted by natural resource and socio-economic variables. Third, we performed a cluster analysis to determine a typology of homogeneous villages.

The variables

The dependant variable is average production per in a village. Then we describe the natural resource variables. Then the other explicative exogenous variables and finally a few intermediary endogenous variables that describe the farming system. We consider natural resource conditions, population density, access to market, land distribution as exogenous variables. Natural resource conditions such as soil acidity, organic matter content, and texture as the result of geology more than the result of farming systems because these characteristics correspond well with the geological map of the country. We consider that rural population density is still the result of ancient history. We consider variables that describe the farming system such as yields, crop importance in the income, fertilizer use as endogenous variables.

Average production per worker: The average production per worker per village is taken as a proxy for labor productivity. The agricultural census of Honduras includes the area of each crop and its yields for each farm. Livestock production is taken from existing livestock and an estimated annual production is taken from the literature (Ruthenberg 1980, Kaimowitz 1996). The household production is then calculated and valued at a national price (Mendoza 1996) for each commodity. We used the same prices for the whole country to be able to compare the productivity between each village independently from the farm gate prices of the location. The production does not distinguish what is sold from what is consumed. It is thus not a monetary income but it is the total production valued at a given price. We multiplied the value of the production per farm by the number of farms of the village to obtain the total production of the village. Then we divided by the number of permanent workers in the village to obtain a proxy for labor productivity.

The map of productivity per worker shows that low productivity is concentrated in the Southwest and in the South of the country which corresponds to several overlapping variables. This map corresponds to common knowledge in Honduras. It does not overlap very well with other indicators of poverty such as public investment. The reason is that some regions are productive but lack the support of the government for different reasons such as low population density. The map does not overlap very well with malnutrition.

The other concepts of poverty in Honduras (FHIS 1995; Oyana et al 1998) show clearly a belt of poverty located in the western mountains and the southern mountains of the country. Indicators of poverty such as malnutrition, poor access to public service, low education are also located in these mountainous areas. On the other side valleys, coastal zones and the eastern part of the country shows much less poverty. Level of poverty is lower because there is more public services, more employment and more intensive agriculture.

We did not keep the farm level in the analysis to reduce the bias against small farms. The census does not include temporary workers. Typically, temporary workers come from the smaller farms and work for larger farms. Thus, productivity for small farms is underestimated because it does not include wages from temporary work while productivity of large farms is over estimated because it does not include the cost of the wages of temporary workers. Consequently, we consider the village as one large farm where the different farms exchange labor.

We did not include cost because costs were not available in the census. The census only reports if there was a use or not of external input such as herbicides or chemical fertilizers. The majority of poor households have very little operational costs as they buy only small quantities of external inputs.

The natural resource variables

Natural resource variables include average slope, altitude, month of rainfall, soil acidity, soil, organic matter. We used the 3,000 geo-referenced soil analysis as a proxy for soil productive potential (Tulio and Barreto 1999). There is a good relation between geology and soil characteristics.

Slope : The slope is an average slope calculated from the area within a circle 60 minutes walk around the village. Slopes have more difficult access, lower soil depth and more erosion. Slope is supposed to be linked with poverty, low yields, less fertilizers. However one can expect more coffee because coffee can be planted on steep slope.

Altitude: Altitude is supposed to mean more poverty, low population density, and large forest area. In Honduras this relation can be reversed since most coffee, bean and horticultural production are located between 800 and 1200 meters. We can suspect a U-shaped curve with less poverty at low altitude and high altitude but most poverty at medium altitude.

Month of rainfalls: We calculated a variable month of rain with more than 30 millimeters. The variable is calculated for each village based on an intrapolation of the climatic stations of Honduras. We did not have the number of days of rain. Also, total rainfalls is not a good indicator of agricultural performances. The maximum rains fall on the Pacific and Atlantic coastal regions. However the Pacific region has a five to six month dry season while the Atlantic coast has no real dry season. More rainy months is supposed to be linked positively to higher yields, higher income, higher population density. A map of monthly rainfalls shows that the distribution of rainfall is better in the western part of the country than in the central eastern part. Also, the map shows that lower altitude areas are better deserved than higher altitude areas which penalizes the southern mountains of the country even if this lack of rainfall can be compensated by lower evapotranspiration at higher altitudes.

Soil acidity: Soil data come from a new CIAT database of 3,000 soil analysis (Tulio and Barreto 1999). The points have been intrapolated with GIS. The acidity of soils in Honduras is very diverse but there is a good correspondence with the geological map. One interesting characteristic is that a large group of soils from the "Padre Miguel" group are very acidic with ph around 4. Low ph is supposed to be linked to low yields of maize and beans and to little possibility of intensification and with higher poverty and malnutrition.

Soil organic matter: Soil organic matter is very often used as a proxy for soil fertility. This indicator is increasingly masked by the use of chemical fertilizers. However we expect soil organic matter content to be linked to higher yield, more diversification and higher productivity.

Clay content: Clay content was used as a proxy for texture. Regions with clay soils have more problems of waterlogging and drainage but less problems of drought.

Socio-economic variables

We included several socio-economic variables that can have an influence on productivity.

Population density: The variable population density takes the population of the 1988 population census of rural villages and divides this population by the total area reported in the agricultural census. This area includes cropland, pastures and forest. Interviewed farmers tend to diminish the real size of their farms to reduce the property tax. Another problem is that many farmers have plots in other villages or municipalities and these plots are reported in the census as being part of the village. The variable population density is thus a rough approximation of the real population density of the village.

Access to road: We calculated the time in hours between each village and the next town counting 2000 inhabitants or more at 30 km/hour. In Honduras a 2000 habitant town is already an active market. The map of road access in Honduras shows travel time of 0 to 13 hours in the most remote areas. The eastern part of the country is the less well connected.

Access to port: Access to port is the distance of each village to the port of San Lorenzo on the Pacific Ocean or to the port of Porto Cortes on the Atlantic Ocean. This variable is complementary to the former variable and is supposed to be a proxy for input prices.

Land concentration: The variable land concentration is used to describe the problem of inequality of access to land. The variable is supposed to explain the loss of productivity due to land concentration. The variable is the *gini* coefficient within the village (Deaton 1997) which goes from 0 to 1 if the farms are all of equal size. This variable is theoretically not correlated to population density. Population density is a proxy for average farm size while the *gini* coefficient is a proxy for unequal size of farms within the village.

Education: Education proxy is the average number of year of schooling per farmer per village.

Ethnicity: We did include ethnicity because indigenous groups are usually less connected to the market than mix groups. There is a risk of multicollinearity with altitude, slope and access.

Extension: Extension is calculated as the percent of farm within the village than have had technical assistant in the last month. There has been many extension programs everywhere in Honduras. These programs have had different periods of action, different strategies and different intensity which we do not know. We suspect that extension service have had a strong impact on productivity in the coffee area.

Credit: The variable credit is the proportion of farmers who have had a formal credit in the past year.

Land tenure: The variable land ownership is the proportion of area of the village that is under private ownership. The rest of the area is communal, national or rented.

Farming system variables

We added the characteristics of the farming system of the villages to calculate the correlation with the previous exogenous variables. These farming system variables are considered endogenous.

Importance of the different activities: The production of the mains crops in each village is divided by the total production of the village. This ratio indicates the importance of the crop within the production system.
Crop yields: Yields of maize and beans aggregate the production of the two rainy seasons. It appears that yields are lower in the south in the acidic region which correspond to the "Padre Miguel" soils. Yields are usually higher in the valleys near the road because of massive fertilization. There is only a pattern of higher yields near the roads and cities and in the vegetable areas.
Fertilizer use: Percentage of farmers from the village using fertilizers or not.
Pesticide use: Percentage of farmers from the village using pesticides or not.
Irrigation: The percentage of irrigated area within the village area serves is the proxy for irrigation.
Conservation practices: The percentage of area protected with conservation practices within the village is the proxy for area.
New seed adoption: The percentage of farms having adopted new germplasm in the past year. It can be any crop and any area of the farm.

Correlations

We used Pearson correlations which are linear correlations (table 1). Variables with better non linear correlations are mentioned in the text. As a rule of thumb we only report variables having more than 0.2 correlation. Sometimes we mention lower correlations when it come to a surprise.

Correlations of labor productivity with other variables

The highest correlation of productivity is with month of rainfalls because a longer rainy season allows a better second crop per year. Surprisingly the relation with total quantity of rainfall per year is very low. This results comes from the characteristic of the southern region which is less productive despite high rainfalls but with a long dry season while the more productive region Northern region enjoys 12 months of rainfalls with the same total amount of rainfalls. Elevation has little direct relation with productivity.

Soil characteristics such as field capacity, clay content, acidity have a small negative relation with productivity. Soil organic matter has a small positive relation with productivity.

Among the socioeconomic variables access, education and extension have a positive relation. Population density and land concentration have a negative relation.

Farming system variables have a relation with productivity. The importance of coffee in the production is the most correlated with productivity while importance of maize in the production has a negative sign. Productivity is also related to yields of maize and bean, to tractor and new germplasm.

In conclusion, the most productive villages are the villages with low population density (large farms), the villages producing mainly coffee (and which do not necessarily have low population density) and the village having high yields of maize and beans. As we shall see, it does not mean that productive villages demonstrate simultaneously the three characteristics together.

Correlations natural resources variables with other variables

Month of rainfall is better related to altitude through a quadratic function as we explained that the rainy season is short in the Southern coastal region, longer in the mountain and even longer in the northern coast. As we have seen months of rainfall is also related to higher productivity, higher yields and animal traction.

Elevation is related negatively with month of rainfalls, total rainfalls. Elevation is related positively with slope. Elevation is also related to poor access, more indigenous villages, more coffee, less livestock, more technical assistance, more land conservation, more fertilization, less use of pesticides, and more acid soils.

Soil clay content is related to more livestock, more maize and more coffee in the total production, higher elevation, indigenous groups, more coffee, small farms and steeper slope. Soil organic matter is related with elevation, longer rainy season, lower ph and slope. It is also related to importance of coffee and importance of livestock.
Clay content is related to less education and to more indigenous groups.

Correlations of the socio-economic variables with other variables

The variable time of access to the closest town has a positive correlation with slopes which means slopes increase access time. The indigenous group is only related to elevation, more soil clay content, less pesticides. Population density is related to land concentration (land distribution), lower productivity. Large farms are related with livestock and flat land.

Correlations of the farming system variables with other variables

Importance of coffee is related to better access to the capital city, higher altitude, slopes, acidic soils, more soil organic matter and steeper slopes. Coffee is also related to less importance of other activities such as maize and livestock, to less pesticides, credit and technical assistance.
More maize in the total production is related to lower elevation, lower productivity, less pesticides, less café, less pesticides, higher maize yield, more land concentration and less education. More beans in the production is related with less total rainfalls, higher altitude, less acidic soils, higher yields of maize and beans, less coffee and less livestock. More livestock in the production is related to lower elevation, large farm, poor access to the capital, competition with bean and coffee and lower soil organic matter and better education.
Use of fertilizer is related to use of pesticides, germplasm, elevation, animal traction, tractor, soil acidity, maiz yieldscredit and conservation, technical assistance.
Use of pesticides is related to total rainfall but little to month of rainfalls. Use of pesticides is negatively related to coffee importance in the production, positively to yields of maize and bean.

The listing of the different relations might look too complex to help draw a coherent big picture of the situation. However, the exercise is necessary to avoid severe muticollinearity in the following regression model.

Linear mutivariate regression

We ran a multivariate linear regressions with labor productivity as dependant variables and 15 variables of socio-economic and natural resource variables (Table). We expelled the independent variables with strong correlation with other independent variables to avoid multicollinearity. The remaining variables are population density, land distribution, access to the two main ports, months of rain, slope, altitude, soil organic matter, soil clay content, soil acidity, adoption of new germplasm. Germplasm excepted we did not include any of the farming system variables because we consider them endogenous to the system.

Because we used a census the t-test and the F-test have little meaning. These two popular tests have a better meaning with smaller sample data. Because of the high number of variables we have a large number of significant variables even if these are poor predictors. We considered the adjusted coefficient of correlation, the sign of the 8 coefficient and the size of the coefficient 8 for each variable.

The adjusted coefficient of correlation reached 0.32, a relatively low coefficient but characteristic for the data we have at hand and the model we applied. Relations between this type of variables are usually not strong for four reasons. First, the data is not very precise. Many maps lack the desired level of detail and some of the spatial data for soils or climate are rough extrapolations of samples of climatic stations and soil analysis. Second, the theory is still weak to explain why individuals and villages respond differently to many external variables. For instance the variable access to market can be calculated in different ways. It requires first a good analysis of what matters most. Its it the sea-port? Is it the inland cities? Third, we did not try different functional forms than the linear one. The plotting of the different variables against the dependant variable did not show much better results. Fourth, a large fraction of the explanation comes from history. Individual villages can react in many different ways to similar conditions. These reactions are long term adaptation to external pressures. There might be some lags in villages reaction to new conditions. We also applied the model to more homogenous regions but the coefficient of correlation did not improve substantially. Similarly we tried other functional forms for some variables but we could not improve the adjusted coefficient of correlation.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.574[a]	.329	.325	8226.814

a. Predictors: (Constant), TECN_AS, LAB_TEMP, N_TOT, LABOR_PE, POP_DENS, LAND_TEN, ACCESS, CLAY, RAIN_M, SEED, GINI_COE, ETNIA2_I, SOIL_CON, SLOPE_1K, BUFFE_PH, LAND_CON, SCHOLAR, CREDIT, ACCESS_S, ELEV

However, the relations between variables were consistent enough to draw coherent conclusions in harmony
with common sense and with what is occurring in Honduras. For some variables we will see that the results challenged the theory but for satisfactory reasons. We organized the results around each variable of the model.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3451.697	2377.720		1.452	.147
	ACCESS	-107.725	18.908	-.107	-5.697	.000
	ACCESS_S	148.852	9.268	.314	16.061	.000
	BUFFE_PH	500.138	265.407	.032	1.884	.060
	CLAY	-14.864	19.373	-.012	-.767	.443
	CREDIT	19.225	6.416	.055	2.997	.003
	ELEV	-6.09E-02	.437	-.003	-.139	.889
	ETNIA2_I	-233.836	74.217	-.049	-3.151	.002
	GINI_COE	-20466.7	1661.432	-.191	-12.319	.000
	LAB_TEMP	320.124	91.155	.054	3.512	.000
	LABOR_PE	95.370	70.831	.020	1.346	.178
	LAND_CON	.218	.234	.015	.931	.352
	LAND_TEN	865.964	457.372	.029	1.893	.058
	N_TOT	123.265	332.948	.006	.370	.711
	POP_DENS	-118.856	17.936	-.097	-6.627	.000
	RAIN_M	1903.807	97.467	.307	19.533	.000
	SCHOLAR	592.780	58.112	.167	10.201	.000
	SEED	135.754	11.342	.189	11.969	.000
	SLOPE_1K	64.985	96.353	.012	.674	.500
	SOIL_CON	-4.949	17.367	-.005	-.285	.776
	TECN_AS	18.983	6.425	.054	2.955	.003

a. Dependent Variable: M_INCOME

The non significant variables are soil organic matter, pH, clay content, nitrogen content, permanent workers in the village, slope, altitude, land tenure. The soil characteristics are not significant on overall production which does not mean that soil characteristics are not important for individual farmers. We think that the analysis of the soil database has to be improved especially the intrapolation.

The significant variables are month of rainfalls, access to the next 10,000 inhabitant city, ethnic groups, land concentration, population density, temporary workers in the village, new germplasm, technical assistance, education.

As we have seen length of the rainy season has a large impact since one more month of rain would increase the production by 10%.

Population density has a negative sign which means that population pressure depresses incomes per worker. Population density is equivalent to the average size of the farms. Honduran farmers have not yet intensified their small farms to compensate for the small size. Another way to interpret is to say that if the population density of the villages could be decreased by ten persons, productivity per worker would increase by $10 which is very low compared to the overall productivity.

The variable access time to the next small town has a negative sign which means that better secondary and tertiary road network would increase productivity. The estimator of access to the next town suggests that if travel time could be reduced by one hour from the current 7 hours in average the productivity could increase by only $10 dollars per worker per year. This number is also low. A zoom on the map shows that villages remote from a small town are less productive than the one close to small towns. Globally it means that the focus should be given to tertiary roads to extract more products.

The distance from the villages to the main large cities has a positive sign which means that the most productive villages are the more distant to the four largest cities. Indeed, the most productive villages, which produce livestock, coffee or banana are usually distant from the main cities. Furthermore, the large international Banana companies which would have improved the productivity of the villages located close to cities were not included in the census. To add to the confusion the poorest villages of Honduras are located close to Choluteca and Tegucigalpa. The reason of their low productivity is the length of the dry season not their good access.

However concluding that reducing distances between small towns and large towns would decrease productivity is wrong. Reducing travel time would improve the traffic and reduce transport cost. What the sign means is that road network is not the main factor of productivity in Honduras. Rainfall is the main determinant factor of productivity.

Extension services have a strong relation with productivity. Each additional percent of the village farm that has access to extension services increases average productivity per farm by $3 dollars per permanent worker. However, it might be also an inverse causality since extension services are usually stronger in already productive regions.

Average years of schooling is related to higher productivity since each new year of schooling increases average worker productivity by $40 which is 3%. Here again the causal relation might be reversed since less productive villages are less likely to obtain public investment such as schools. The overlapping with the school map confirm that poorer villages have less schools.

Indigenous villages are less productive. Indigenous farms were given a 1 and other villages a 0. In average Honduran villages have 0.83. This means that if everybody was not indigenous productivity would increase by less than one dollar. In fact, indigenous villages are located in more remote areas with shorter rainy season.

Cluster analysis

We performed a cluster analysis with the K-mean cluster method. This procedure identifies relatively homogeneous groups of cases based on selected variables. We used squared Euclidian distance measure the distance between the variables. After several run we decided to take 6 groups. Table 2 shows the main characteristics of the 6 groups. Map 1 shows the spatial distribution of the 3,731 villages with different colors according to their group membership. The six groups are the following:

The rich coastal villages: First, there is a small group of 24 villages located in the more humid coastal departments of the north (Pink points on the map). In average they have very long road access to the seaport or to the next town because a significant number of the villages are located deep in the Mosquitia region where they connect mainly by boat. Surprisingly productivity is the highest with $6,000 of production per permanent worker. These villages produce intensively maize, bean, banana on large farms thanks to a low population density. These villages use the largest quantity of pesticides and fertilizers. More alphabetized but have very little technical assistance or credit. These villages use the most temporary workers but include less private property.

The rich ranchers: The second group has 153 villages mainly located in four or five inland valleys where they receive less rainfall than the first group but more than all the other groups (yellow points on the map). Production is close to $4,000 and consist mainly of livestock, maize, bean with high yields on large farms.

The rich coffee producers: The third group is made of 429 villages located everywhere in the country but not in the lower South Western quarter (Yellow points in the map). Income is close to $3,000 and comes mainly from coffee and livestock. In average these villages are located at higher altitude. These villages benefit from more credit and from more technical assistance. They produce also some onion and cabbage with small irrigation.

The poor coffee producer: The 805 villages of the fourth group are well spread over the country (blue points on the map) where they receive less rainfall than the other groups. They produce for a little more than $2,000 per worker. Farms are smaller in average with 10 hectares. These villages produce mainly maize and coffee and yields are lower. These villages benefit from good technical assistance and from credit. They also produce some vegetables with small irrigation.

The poor maize producers: The 873 villages of the fifth group are located in the western half of the country (dark pink points in the map). Productivity comes close to $1400 per worker. The rainy season is shorter than for he previous groups. They have less coffee and livestock than the previous groups but more maize. Yields are lower and farms smaller.

The very poor maize producers: The 680 villages of the sixth group are also located in the western half of the country with a larger concentration in the south (dark pink points in the map). Productivity is close to $800 per year which come close to 2$ per day. They receive only 8 month of rainfalls which explains the lower yields and the relative importance of maize in the production. Surprisingly the poorest group has the shorter access time to the seaport of San Lorenzo. This group also has the shorter schooling time and the lowest access to credit.

Some groups have special characteristics but with little relation with productivity. Land conservation techniques are more frequent with less productive maize and coffee producers. These are much less frequent with ranchers and absent with coastal large farms. Proportion of land privately owned is similar in all groups but the few coastal villages. Many variables are not very different between groups. Vegetable production is extremely low in all groups. Sugar cane production is small but more important in the "ranchers villages" because they are located in the inland valleys. Soil characteristics are similar in all groups. Even if clay content is decreasing with productivity, clay content is not considered significant in the regression. The *gini* coefficient of land distribution is high everywhere which means that land is very concentrated. Land concentration is decreasing exactly with productivity. We have seen that land concentration has an impact on overall productivity.

The first conclusion of the cluster analysis shown on the map is that there is a clear geographical pattern of productivity. The concentration of most productive villages in the Eastern half of the country. The northern coast is a patch of all type of villages indicating a strong proletarization of the coastal economy. The less productive villages are in fact located next to large banana plantations located in another "village". As we already said the salary of the plantation worker is not accounted in the village where he leaves. The North Western part of the country is a patch of less productive villages mainly involved in coffee production. The Southern half of the country is uniformly less productive but a few villages in the coastal Choluteca plain.

POLICY IMPLICATIONS

There is scope for policies to improve the overall productivity of Honduran agriculture because some of the natural resource constraints are not strict, meaning that good policies can help communities overcome these constraints. Long dry season can be overcome with irrigation. Inaccessibility can be overcome by improving the road network. Poor soils can be improved by fostering a well targeted fertilization program.

The socio-economic variables are also important to explain productivity. There is even more scope for policies to impact on socio-economic variables than on natural resource variables. Land concentration can be targeted. Extension services and schooling can be improved. Credit can be facilitated. Road connections can be improved.

There is a relation between average size of the village (as proxy for population density) and productivity. At the same time unequal land distribution within the village diminishes overall productivity. These results suggest that an agrarian reform would increase productivity. This view is shared by many analysts in Honduras. Large fertile, flat areas are not used but for speculation and tax evasion. However some past land reforms have shown disappointing results such as beneficiaries of the land reform selling back their land to larger land owners. Some economists suggest that bringing inflation under control might make land speculation less attractive and absentee landlord less numerous. This might lead to a more productive use of land.

Population density is very high in the dry south where productivity is low. Currently there is a large migration movement to the under-populated Eastern part of the country where productivity is much higher. Further East there is an active agricultural frontiers toward famous protected areas. The analysis is not very optimist about the chances of stopping the movement by intensifying agriculture in the Southern mountains where density is higher than 150 inhabitant per square kilometers and where irrigation possibilities are small. A large landless population and largely underused valleys are the main policy challenge for Honduras in the coming decades.

CONCLUSION

The analysis shows the relation between conditioning variables and labor productivity in Honduras. The method can applied very quickly and can be reduced to smaller areas where projects and program want to focus. The combination of the three statistic techniques, correlation, regression and cluster, improves the understanding of the Honduran situation. Correlation gives a sense of the relations between variables. The regression predicts roughly what would be the return of different investments. The cluster helps to improve the understanding of the different groups. One can increase easily the number of clusters to identify in more details some groups or add new variables. Finally the GIS allows for a much better visualization of the results by non statisticians. The methodology is likely to improve over time with more detailed maps and better intrapolation models.

The analysis also suggest that censuses should include much more focus on costs and especially on labor costs which are so determinant for poverty. One could also expect more precision about the natural environment of the farm even if these would just be rough estimations. The questionnaire should put more detail on the location of the different farms because some large farmers have several farms in different villages. There is scope to reduce the detail on the production side of the questionnaire. Last, there should be a mechanism to reduce the tendency to underestimate the area of the farm. With the increasing number of land titles future censuses should gain in quality.

Gis is becoming a powerful instrument to help policy makers take more informed decisions. The study has shown that GIS can go beyond map making without developing complex models. The same methodology can be applied to smaller areas and to other research questions.

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Final Cluster Centers

	Cluster					
	1	2	3	4	5	6
ACC_BIG4	21.52907	1.41500	22.65439	26.71248	13.63000	16.64167
ACCESS	6.85729	1.00000	3.02439	7.83861	2.09524	.83333
BEAN_YI	8.68985	10.90477	8.37687	7.89216	8.58443	7.97337
BUFFE_PH	4.95781	5.05000	4.88659	4.96070	5.27619	4.76667
CLAY	26.29369	30.00000	23.25610	25.60000	23.80952	25.33333
CREDIT	12.87741	12.82412	35.10802	27.40710	29.10854	39.98383
ELEV	380.61634	100.00000	819.41463	923.85523	527.71429	729.50000
ETNIA2_I	.36298	.50000	1.21951	1.14370	.09524	1.50000
FERT	30.47457	32.60261	48.95409	35.45506	48.54004	54.63387
FIEL_CA	21.86350	23.50000	20.79268	21.90349	20.33333	21.50000
GINI_COE	.78318	.92228	.85437	.78851	.88229	.89088
HERB_INS	45.82209	47.34142	35.30959	26.60202	50.18749	44.18995
IBANANA	.00698	.00000	.00407	.00398	.00516	.00614
IBEAN	.08171	.00620	.10200	.13163	.08431	.09695
ICATTLE	.11894	.34223	.11295	.08131	.14305	.12575
ICOFFEE	.05554	.00273	.14440	.19841	.08044	.19023
IMAIZE	.34603	.21675	.34511	.32122	.33822	.25383
IONION	.00032	.00087	.00320	.00320	.00354	.00627
ISUGAR	.01936	.00562	.01540	.02679	.01040	.00575
ITOMATO	.00134	.00000	.00579	.00418	.01057	.00610
LAB_TEMP	.88756	22.00030	1.71380	.72524	1.56257	3.02933
LABOR_PE	1.58212	.44023	1.20709	1.24029	1.24284	1.52988
LAND_CON	58.93175	13545.00	1504.220	83.05094	4109.524	7897.500
LAND_TEN	.58691	.85707	.76333	.65583	.73189	.80791
MAIZE_YI	19.15978	21.92261	21.24459	18.78764	21.55426	22.03264
N_TOT	.87518	.60000	.82927	.88965	.69047	.63333
OXES	5.10456	12.12687	28.25786	22.78175	29.36381	27.89549
POP_DENS	1.49698	.24621	.48233	1.59891	.33471	.31946
R_D_A	1.58212	.44023	1.20709	1.24029	1.24284	1.52988
RAIN_M	9.77146	9.00000	9.35366	9.16944	9.33333	8.33333
RAIN_TOT	2109.077	2290.500	1348.232	1337.103	1502.667	1398.000
SCHOLAR	8.39042	14.21149	10.45557	7.91425	11.16849	15.11801
SEED	7.17455	22.69123	19.98165	10.97355	23.86018	28.81282
SLOPE_1K	1.92275	.15000	1.48134	2.67735	.82381	1.13000
TECN_AS	15.46853	9.04405	37.50832	27.03596	33.67023	37.92360
TEMPER	30.22647	31.50000	28.13415	27.75335	29.71429	28.66667
TRACTOR	3.48130	14.69217	16.82414	6.87514	27.15576	22.45519

Map 1:Tipology of Villages in Honduras