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Economic Development and Convergence Revisited: the Role of Agricultural Modernization

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Abstract: In earlier debates on economic development, the agricultural sector's role was somewhat controversial. While dualistic models highlighted the importance of agriculture the mainstream literature placed a greater emphasis on the creation of a modern industrial sector. Soon agriculture disappeared from the mainstream development literature to re-emerge recently with a variety of multiple-sector growth models emphasizing the key role of agriculture. This paper is an empirical cross-country analysis of agriculture's role in economic development. The focus is the importance of agricultural modernization as a precondition for convergence in postwar growth rates as well as an indicator for overall growth and wellbeing.

Keywords: agriculture, modernization, convergence, growth, well-being

Economic Development and Convergence Revisited: the Role of Agricultural Modernization

Initially development economics concentrated on questions concerning the industrialization process. The main questions had to do with how to modernize through overcoming the constraints of traditional society. The latter was often linked with agriculture and rural people, commonly called peasant agriculture. This sector was generally thought to act as a drag on the development process. Thus tradition and peasant farming were obstacles, systems which had to be reduced and eventually eliminated if modernization was to succeed.

However, economic historians often saw agriculture as playing a critical role in the industrialization of England. Dualistic models also directly modeled traditional agriculture in the long-run growth process. In these models the conclusion often implied that the long-run growth process must be a balanced one with agricultural productivity a necessary condition for eventual industrial/manufacturing growth. In other words, if productivity in agriculture remained stagnant, the development of a modern manufacturing sector would be limited.

Throughout much of the 1980s and 1990s much of the analysis of the role/contribution of agriculture was carried out by agricultural economists. Much of this work concentrated on technological innovation in agriculture, the institutional structure necessary to foster technical innovation, etc. However, in terms of long-run growth models, agriculture disappeared. This sector and its role were, for the most part, ignored in models of long-run growth emphasizing industrialization and manufacturing.

Recently, however, one finds a re-emergence of interest in agriculture. Agriculture has been increasingly incorporated into models of long-run growth. The argument in most of these models is that agriculture and the productivity of agriculture is the key to understanding the timing of the shift from an agrarian based to an industrially based society. In addition, some non-traditional roles have been attributed to agriculture in the development process.

Given the literature referred to above on the importance of agriculture in the development process, the hypothesis in this paper concerning agriculture is that high productivity in this sector is a necessary precondition for industrial growth. The implication of such a hypothesis would be that countries which did not have this precondition would not grow as fast as those that did. Therefore, economic convergence, when poorer countries grow faster than richer countries leading to a convergence in growth rates and standards of living, is not likely to occur for countries within which agricultural productivity is historically low. The existing convergence literature indicates very little support for the idea that unconditional convergence occurs. This paper begins by testing for unconditional convergence utilizing a postwar cross-section of countries. If such convergence is found not to exist, the next step is to test whether convergence requires a precondition of agricultural modernization which is presumed to imply high productivity. Once that proposition is established, an attempt is made to test how robust this connection between agricultural preconditions and long-term growth is. Finally, the non-traditional views of the role of agriculture in development, which indicate that agricultural productivity should be significant in determining levels of human development, are tested by utilizing the human development index, which incorporates measures of life span, education, and GDP.

Before going into the details of the paper it needs to be clarified that the importance of agricultural sector is not calculated as a traditional productivity measure by measuring units of agricultural output per unit of labor or land or based on some index of inputs. One reason for this is such measures of agricultural productivity are not available for a number of countries for the time period covered in this paper. Thus a different and unique perspective on agricultural productivity is introduced here. Here the importance of agricultural is measured by the amount of investment made on land to modernize it and thereby make it productive. Theoretically this may be more appropriate than the traditional measures. This is due to the fact that agricultural productivity could be high because a particular nation is well endowed with natural resources.

High productivity, in this situation, will likely decline with depletion of natural resources unless some steps are taken to maintain this productivity. On the other hand, it is being hypothesized here that countries which made some effort towards improving or maintaining their agricultural productivity by investing in it and modernizing the agricultural sector would most likely be the ones who would continue to reap the benefits from increased agricultural productivity. In other words, this paper measures *effort* or *investment* rather than *potential* for agricultural productivity. For the above reasons the focus in this paper is the importance of agricultural modernization for economic growth and well-being.

The paper is organized as follows. Section I will review the literature, both traditional and non-traditional, on agriculture's role in the growth and development process. Section II will discuss the data utilized as well as the empirical methodology that is applied. Section III will summarize the empirical results, while Section IV summarizes the paper and presents the important conclusions.

I

Much of the early thinking on economic development ignored agriculture altogether. For example, Rosenstein-Rodan's (1943) early work concentrated on manufacturing and industry. He argued that the piecemeal establishment of manufacturing in poor regions lacking infrastructure would not likely be successful. Instead, investment in industry and manufacturing had to be on a broad front such that various industries could create markets for each other's products.

Perhaps the best known of these early theories was that developed by Hirschman (1958). He argued that industries or production processes were characterized by backward and forward linkages depending upon whether production of the industry stimulated the expansion of suppliers of inputs or the processors of output. Some industries possessed strong backward and forward linkages and thus if established would likely stimulate strong growth around it. However, agriculture's linkages were mainly of the forward variety and not very strong. Thus the expansion of agriculture was not likely to stimulate further development.

There were a set of theories which, however, did see a role in the development process for agriculture. These were dualistic theories of development constructed by Lewis (1954), Ranis and Fei (1961), and Jorgenson (1961). These theories divided the less developed economy into the traditional and modern sector. The modern sector was driven by profit maximization and the accumulation of physical capital. The traditional sector was subsistence oriented and usually thought to be dominated by peasant agricultural production. This sector was characterized by output sharing mechanisms rather than profit maximization.

In many of these models it was presumed that the traditional sector was characterized by surplus labor. That is, there was so much labor in this sector that it could be withdrawn and put to productive work in the modern sector without any fall in output in the traditional sector. In effect, "free growth" was possible through mobilization of labor for modern production. However, once surplus labor was exhausted, then the expansion of the modern sector might very well be strangled. Continued withdrawal of labor would lead to falling output in the traditional sector leading to a rise in the relative price of the traditional sector output relative to that in the modern sector. If the traditional sector produces mainly food, the rising relative cost of food would push up wages to the modern sector, cutting into profits, reducing investment and the expansion of this sector. The growth process would likely grind to a halt. Thus overall growth was dependent upon a balanced expansion of both sectors with neither racing too far ahead of the other. This would keep the relative cost of food low, maintain profits in the modern sector, and spur modern sector investment.

Johnston and Mellor (1961) built upon these ideas in their analysis of the role of agriculture in overall economic development. They argued that agriculture supplied the labor necessary to man the modern sector firms as well as the food necessary to feed that labor. In addition, the agricultural sector was seen as serving as a market for the produce of the modern sector, a stimulus from the demand side. Finally, perhaps most importantly, agriculture was likely to serve as the main source of savings necessary to finance the expansion of the modern sector.

After these developments, agriculture disappeared from general models aimed at analyzing economic growth and development. Instead, much of the literature concerned with agriculture concentrated on analyzing productivity growth in the traditional, agricultural sector. Perhaps the most interesting and innovative work in this area has been undertaken by Hayami and Ruttan (1985). They developed a theory of induced innovation. From this perspective, technology can be divided into two broad categories, mechanical and biochemical. Changes in the relative price of inputs induce farmers to search for technologies that substitute for the increasingly scarce factor. Because biochemical technologies are subject to problems stemming from non-excludability of the benefits, a public institutional structure must be established to provide biochemical technologies. In regions where labor and fertilizer are relatively cheap and land is becoming relatively scarce, the public institutional structure will respond to the needs of farmers by developing techniques of production which are land saving (biochemical).

As one can see, this literature was not so much concerned with agriculture's role in the growth process, instead it was concerned with the process by which agricultural productivity increases. These ideas were indeed powerful, but the modeling of the growth process tended to neglect agriculture and thus obscure its role in the process of development.

Recently, multiple sector growth models have begun to be constructed with agricultural sectors. Matsuyama (1991) developed an endogenous, two sector growth model. In this model the engine of growth, the driving force, was learning by doing in the manufacturing sector. He compared and contrasted the implications of a closed and open economy model. In the closed economy case, an increase in agricultural productivity spurs overall economic growth since this eases the expansion of learning by doing via manufacturing. However, in the open economy case there is a negative link between agricultural productivity and overall growth. This occurs because the more productive the agricultural sector is, the more resources that are devoted to agriculture based on comparative advantage. This, of course, implies less manufacturing, less learning by doing, and less growth.

The results from Matsuyama's model are of course based on assuming that all learning by doing occurs in manufacturing, none in agriculture. However, learning by doing in manufacturing could enhance productivity in agriculture and perhaps vice versa. More generally, the model's results stem from the assumption that agriculture is, by nature, incapable of sustaining rapid productivity growth. Thus it is inevitable that higher initial productivity in agriculture (exogenously determined) would lower long-run growth.

This idea that productivity growth is slow in agriculture is actually contradicted by empirical analysis. Martin and Mitra (2001) utilize a panel data set for approximately 50 countries over the period 1967-1992 to analyze this issue. They found that at all levels of development technical progress appears to have been faster in agriculture than in manufacturing. In addition, "there is strong evidence of convergence in levels and growth rates of TFP in agriculture, suggesting relatively rapid international dissemination of innovation" (p.417). These results suggest that a large agricultural sector need not be a disadvantage in the overall growth process. It may likely be an advantage if productivity growth is rapid. Thus contrary to the assumption made by Matsuyama, the agricultural sector has significant prospects for rapid productivity growth.

Theorists have now begun to explicitly model the agricultural sector in multiple sector growth models. A recent example of this is provided by the work of Gollin, Parente, and Rogerson (2002). They extend the neoclassical model so as to incorporate an agricultural sector. They attempt to model the structural transformation that comes with development (agriculture shrinking, manufacturing expanding). The intuition of the model can be summarized as follows. Agricultural output per person must reach a certain level before modern technology will be applied to agricultural production and labor can flow out of agriculture and into industry. The rate at which labor can then flow out is determined by the rate of technological change in agriculture. Low agricultural productivity can thus substantially delay the onset of industrialization.

Another example of a long-run growth model that directly incorporates agriculture is the work of Olsson and Hibbs (forthcoming). They have constructed a stages growth model within which societies progress through hunting and gathering, sedentary agriculture, and industrial production. The main focus of the model is that those regions that were initially well endowed biologically and geographically are those regions which progress through to the industrial stage the quickest. In this model, the intermediary stage is sedentary agriculture and it is productivity increases leading to surpluses in this sector that allow for the creation of new knowledge. When knowledge reaches a certain threshold level, the development of industry occurs, i.e., industrial revolution.

These are just a few examples of a developing literature seeking to incorporate agricultural sectors into growth models. Other research has examined new links between agriculture and the growth of the rest of the economy. One can think of these new links as representing non-traditional roles for agriculture. Timmer (1995) argues that agriculture plays a significant role in reducing poverty. The bulk of the poor reside in rural areas so an increase in growth in agriculture has a significant potential for reducing such poverty. In addition, agricultural growth stimulates the development of agribusiness activities as well as stimulating the demand for manufactured inputs. Stringer (2001) further argues that the agricultural sector performs important social welfare functions in developing nations. For example, during an economic downturn or an external income shock or financial crisis, agriculture can act "as a buffer, safety net, and as an economic stabilizer" (p.7). The flexibility of the production process allows for labor to be substituted for capital thus cushioning economic blows. Thus people frequently return to the farm during bad times.

Given the analysis above, several questions suggest themselves. First, does absolute economic convergence occur and, if not, is convergence conditional upon agricultural productivity? In other words, is increased agricultural productivity a condition for economic convergence? Second, if so, is the modernization of agriculture an important determinant of overall growth? Is this effect robust to the inclusion of other variables? Third, given the non-traditional roles for agriculture, does agricultural modernization have a significant impact on human development? Is this impact robust to the inclusion of other variables? The methodology and data that will be utilized to address these questions is discussed in the following section.

II

In order to test for absolute convergence within our sample, the following equation is estimated:

(1) $$GR6095 = a + b\,(LnGDP60) + \varepsilon,$$

where *GR6095* is the average growth rate of our sample countries for the time period 1960 to 1995. The right-hand side variable, *LnGDP60*, is the natural log of GDP per capita in 1960 for each of our sample countries. Of course, ε is the error term. As is common in the literature (Van den Berg, 2001), the sign on the right-hand side variable would tell us something about convergence. If the sign is negative and statistically significant, this would imply that those countries which have the higher GDP per capita will tend to grow slower than those countries with lower GDP per capita. Thus absolute convergence is taking place.

Most studies have found very little evidence in support of absolute convergence. However, there is a substantial literature that conditional convergence does occur. That is, once one accounts for specific variables that influence the long-run, steady state equilibrium, convergence may still be found (convergence to different equilibria). Another way to think of this is that there are certain preconditions that must occur before convergence takes place. It is hypothesized that productive agricultural sectors are a necessary precondition for economic convergence. In order to test this hypothesis, the following equation is estimated

(2) $$GR6095 = a + b(lnGDP60) + c(lnFert65) + \varepsilon,$$

where *lnFert65* is the natural log of fertilizer intensity for the year 1965. The latter is measured as kilograms per hectare of land. This variable is used as a proxy measure for agricultural productivity or the degree of modernization of agriculture in 1965. This proxy variable is used because direct data on agricultural productivity for a large number of countries for that time period is not available.

The intuition behind equation two is fairly obvious. It is hypothesized that high agricultural productivity or a modern agricultural sector is a necessary precondition for convergence to occur. Thus, it is hypothesized that the coefficient c will be positive and statistically significant and the coefficient for b will be negative and statistically significant.

Another way of testing the same hypothesis is to divide the sample countries into two groups, those with above average and those with below average fertilizer intensity in 1965. One would hypothesize absolute convergence for those countries above the average for fertilizer intensity and divergence or no trend for those with below average fertilizer intensity. Thus equation one will be estimated for the two groups. It is hypothesized that b will be negative and statistically significant for those with above average fertilizer intensity and b will be statistically insignificant for those below the average fertilizer intensity.

If indeed agriculture appears to be a precondition for convergence, then the next step is to determine how robust is agriculture's influence on growth. This is tested by estimating the following equation by adding one variable at a time.

$$(3) \qquad GR6095 = a + b(lnGDP60) + c(lnFert65) + d(School) + e(lnInv6095) + f(Open\ 6095) + g(ICRGE80) + h(Statehist) + I(EA) + j(LatA) + j(MENA) + k(SSA) + l(SA) + m(WE) + \varepsilon.$$

The additional variables that are added are a measure for educational attainment given by *School* which is the average years of total schooling of the population from 1960 to 1985, a measure of the investment given by *lnInv6095* which is the natural log of average investment from 1960 to 1995, a measure of openness of the economy given by *Open6095* which is the average ratio of exports plus imports divided by GDP for the period 1960 to 1995, a measure of institutional quality given by *ICRGE80* which is an the average of five different measures of institutional quality, a variable for state antiquity given by *Statehist* , and a series of dummy variables: East Asia (*EA*), Latin America (*LatA*), middle East and North Africa (*MENA*), Sub-Saharan Africa (*SSA*), South Asia (*SA*), and Western Europe (*WE*).

Several of these variables need further explanation. The *Statehist* variable is an index of how long a nation state has been in existence for various regions of the world. The time period covered is from 1 to 1950 C.E. The higher the index number, the longer a state has been in existence. The *ICRGE80* variable is an average of measures of corruption, repudiation of contracts, expropriation risk, rule of law, and bureaucratic quality for the year 1980. The higher this average, the better the quality of institutions.

Much of the data used to estimate this and the previous equation are taken from Bockstette, Chanda, and Putterman (2002). Specifically, *GR6095*, *lnGDP60*, *lnInv6095*, *ICRGE80*, *Statehist*, and the regional dummies all come from this paper. The *School* variable comes from Barro and Lee (1993). The fertilizer intensity variable is taken from the World Resources Institute (www.wri.org/) who in turn derived the data from the FAO. The measure of openness, exports plus imports divided by GDP, is taken from the Penn World Tables (PWT) version 6.1.

Since it may be argued that the intensity of fertilizer usage may be a narrow measure of agricultural modernization, a more sophisticated measure of agricultural productivity or agricultural modernization was derived by gathering data from the World Resources Institute (who in turn gathered the data from the FAO) on tractor intensity, which is tractors per hectare and by including a measure of average years of schooling of the population in 1960. The reason behind including a measure of education along with mechanization in farming is to recognize that increased human capital can result in better technology and a more efficient utilization of the available agricultural technology. These two additional terms are multiplied by the fertilizer intensity term to create an interaction term. It is expected that this interaction term gives a more accurate representation of the degree to which the agricultural sector was modernized. This interaction term is referred to henceforth as *AgModern*. It was substituted into equation (3) for fertilizer intensity and the model was re-estimated to see if the same relationships are found to hold with a more sophisticated treatment of agricultural modernization.

The discussion of the previous section indicated that agriculture is likely to play an important role in terms of providing a safety net for a society lacking formal programs aimed at social welfare. Under such assumption one would expect that the level of human development would also be influenced by agricultural modernization. In order to test this proposition, an average of the human development index (*HDI*) from 1975 to 1995 is used as the dependent variable. The data used to calculate this measure is taken from various issues of the *Human Development Report*. Equation (3) is re-estimated once again, but with the average human development index (*HDI7595*) as the dependent variable and with *AgModern* as a measure of agricultural modernization. Thus the following equation is estimated to test the hypothesis.

$$(4) \quad HDI7595 = \alpha + \beta(AgModern) + \gamma(lnInv6095) + \delta(ICRGE80) + \zeta(Open6095) + \eta(Statehist) + \theta(EA) + \lambda(LatA) + \mu(MENA) + \nu(SSA) + \psi(SA) + \varphi(WE) + \varepsilon.$$

Notice that neither *lnGDP60* nor *School* appear in the equation. This is due to the fact that *HDI7595* incorporates both into the measure of human development.

The data set covers 90 countries but Iceland was removed because the fertilizer values for Iceland made it an outlier thus reducing the sample size 89. For various regressions some countries are missing values, thus the size of the sample accordingly shrinks. The next section of the paper will discuss and interpret the results.

III

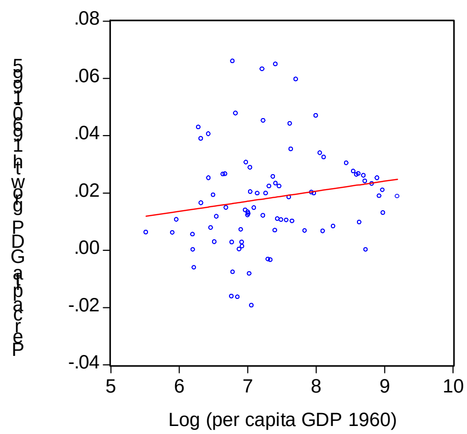
In the previous section equation (1) was introduced as the basic equation to be estimated to test for absolute convergence in growth rates between countries. The results from estimating equation (1) are as follows:

$$GR6095 = -0.007 + .004Ln(GDP60) + \varepsilon$$
(t-statistic) *(-0.57)* *(2.09)*

N = 89
D.W. = 1.98.

Figure 1 is a graphical representation of the above regression.

Figure 1: All countries in sample



As can be seen, both the scatter plot above as well as the regression results provides evidence to support divergence in growth rates rather than convergence. That is, countries that were rich in 1960 grew relatively richer and countries that were poor in 1960 grew relatively poorer over time.

It was further hypothesized in the previous section that countries with better initial agricultural precondition are most likely to be the countries which grow faster. That is, one should find convergence between countries that have the necessary agricultural precondition. Thus, fertilizer intensity in 1965 is introduced into equation (1) to give us equation (2) to test for conditional convergence. The following are the results from estimating (2) using simple OLS. All results are White heteroscdasticity-consistent standard errors and covariances.

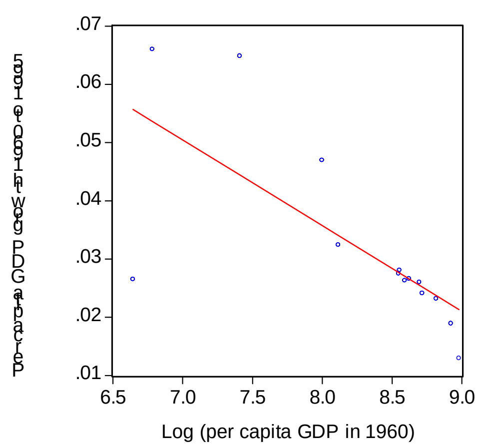
$$GR6095 = 0.05 - 0.01(lnGDP60) + 0.01(\text{lnFert65}) + \varepsilon$$
(t-stat) *(2.92)* *(2.49)* *(4.83)*

N = 89
D. W = 1.9.

The results above show that once we control for agricultural productivity, we find evidence for conditional convergence in the sample.

If agricultural precondition is found to be necessary for conditional convergence to take place it can be inferred that one can then expect to find absolute convergence between countries with high agricultural productivity but not so among those with low agricultural productivity. Accordingly the sample of countries is subdivided into those with above-average agricultural productivity (in this case above average fertilizer intensity in 1965) and those below. It is found that 16 countries fall in the above-average agricultural productivity group and the rest fall under. The correlations between per capita GDP growth between 1960 and 1995 and per capita GDP in 1960 in the above average group is -0.71 while the correlation is 0.13 between the identical variables in the group of countries with below average agricultural fertilizer intensity. A simple scatter plot (Figure 2) of per capita GDP growth and initial per capita GDP reveals that countries with initial lower incomes have grown faster in this group of countries. There are only a few (16) countries in this group and most had high per capita GDP to begin with, but the few that had low initial per capita GDP (Jamaica, Japan, Korea, Singapore, and Israel) grew relatively much faster over the period under consideration. Figure 2 looks quite different from Figure 1.

Figure 2: Countries with above-average fertilizer intensity



One can see evidence of convergence in the above-average category of countries. A formal test of absolute convergence from this sample produces the following results:

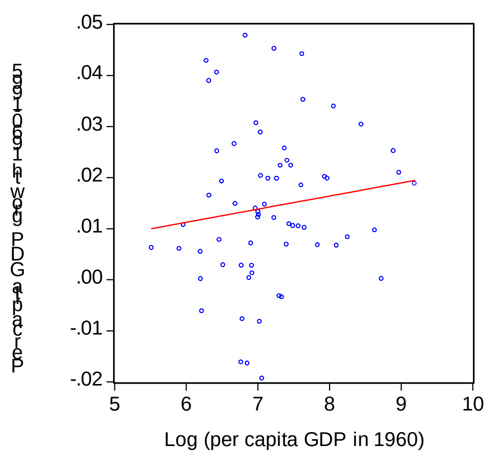
$Gr6095 = 0.15 – 0.01 (lnGDP60) + \varepsilon$
(t stat) (2.37) (1.96)

D.W = 1.85.

One can see that absolute convergence is found to exist within the above-average fertilizer-intensity group.

Next, the attention is focused on the below-average group of countries. A simple scatter of the per capita GDP growth and initial per capita GDP is presented in Figure 3 and the graph looks very similar to Figure 1.

Figure 3: Countries with below-average fertilizer intensity



A formal estimation for the below-average fertilizer-intensity countries produces the following results:

$Gr6095 = -0.004 + 0.002 (lnGDP60) + \varepsilon$
(t stat) (0.28) (1.31)

D.W = 1.69.

It is clear from these results that there is no statistical evidence of convergence within countries that lie in this group.

The evidence so far points to affirmation of the hypothesis made in this paper, that is, agricultural preconditions are necessary for long-run economic growth. This relationship, established in equation (2) is tested for its robustness to the introduction of other variables also established in the literature as having significant impact on growth. Equation (3) is estimated for the sample and the results are presented in Table 1.

In the table below each column represents an individual cross-country regression using simple OLS. All results are based on White heteroscedasticity-consistent standard errors and covariances. All estimations show that there is evidence of conditional convergence within the sample of countries when agricultural productivity is the precondition being imposed. Moreover the results also testify to the robustness of the significant positive impact that fertilizer-intensity has on per capita GDP growth from the mid-1960's to the mid 1990's. The other variables are entered one at a time. However, when the natural log of investment from 1960 to 1995 is included one notices a sudden change in value and significance of the education variable. Even though the R square values keep improving with each additional variable, the sudden change in significance in education might be seen to be a potential multicollinearity problem in the equation. That is, it is possible that the educational attainment of the population was correlated to the investment share in the economy. Therefore to eliminate such a problem, if it exists, equations (7), (8), and (9) are estimated leaving out either the schooling variable or the investment variable. Equation (10) includes all variables and all regional dummies. The results show that there is strong evidence of schooling, state antiquity, and institutional quality having a significant and positive impact of per capita GDP growth in this period of time. Moreover, the results show strong evidence of Sub-Saharan Africa having a negative impact on growth and a relatively weaker evidence of South Asia also having a negative impact on growth. Contrary to the predictions of neoclassical literature, the above estimations do not provide any evidence of openness having a significant impact on per capita GDP growth for the given sample of countries.

Table 1
Different permutations of Equation (3)

Indep	1	2	3	4	5	6	7	8	9	10
variables:										
lnGDP60	-0.006**	-0.01**	-0.04**	-0.01**	-0.02**	-0.01**	-0.01**	-0.02**	-0.01**	-0.02**
t-stat	*(-2.49)*	*(-3.05)*	*(-3.39)*	*(-3.63)*	*(-4.37)*	*(-4.15)*	*(-3.88)*	*(-4.74)*	*(-3.76)*	*(4.37)*
lnFert65	0.01**	0.004**	0.01**	0.004**	0.004**	0.002**	0.002**	0.002**	0.002**	0.002**
t-stat	*(4.84)*	*(3.73)*	*(3.69)*	*(3.75)*	*(3.64)*	*(2.25)*	*(2.94)*	*(2.17)*	*(2.43)*	*(2.27)*
School		0.01**	0.002	0.001	0.005	0.007**		0.008**		0.01**
t-stat		*(2.83)*	*(0.78)*	*(0.37)*	*(1.44)*	*(2.35)*		*(2.75)*		*(2.15)*
lnInv6095			0.01**	0.01**	0.01**	0.007**	0.01**		0.01**	0.002
t-stat			*(3.82)*	*(5.01)*	*(3.62)*	*(2.87)*	*(6.08)*		*(2.97)*	*(0.78)*
Open6095				-7.27E-05	-6.46E-05	-2.45E-05	-2.92E-05	-5.37E-05	-1.33E-05	-1.17E-05
t-stat				*(-1.14)*	*(-1.25)*	*(-0.48)*	*(-0.56)*	*(-0.12)*	*(-0.28)*	*(-0.26)*
ICRGE80					0.003**	0.003**	0.002**	0.004**	0.002**	0.004**
t-stat					*(3.66)*	*(3.18)*	*(2.28)*	*(3.48)*	*(1.98)*	*(2.98)*
Statehist						0.02**	0.02**	0.02**	0.02**	0.02**
t-stat						*(4.39)*	*(3.74)*	*(2.73)*	*(2.05)*	*(2.63)*
EA								0.003	0.001	0.0005
t-stat								*(0.06)*	*(0.32)*	*(0.11)*
LatA								-0.005	-0.02	-0.005
t-stat								*(-1.19)*	*(-1.31)*	*(-1.14)*
MENA								-0.005	-0.001	-0.0006
t-stat								*(-1.13)*	*(-0.23)*	*(-0.13)*
SSA								-0.02**	-0.02**	-0.02**
t-stat								*(-3.11)*	*(-2.38)*	*(-2.58)*
SA								-0.01**	-0.01	-0.01*
t-stat								*(-2.21)*	*(-1.36)*	*(-1.87)*
WE								-0.01	-0.01	-0.01
t-stat								*(-1.69)*	*('-1.32)*	*('-1.62)*
N	89	89	89	89	89	89	89	89	89	89
DW	1.89	2	1.9	1.99	2.12	2.12	2.11	1.69	1.87	1.7
R square	0.3	0.36	0.47	0.5	0.59	0.67	0.66	0.78	0.75	0.77

Note: Dependent variable: per capita GDP growth from 1960 to 1995; a constant term is included in each equation but not reported here; * represents statistical significance at 90% and ** represents statistical significance at 95%

It was mentioned in the previous section that the analysis of the importance of agricultural productivity is taken a step further by moving from a simple fertilizer intensity measure of agricultural productivity to a newer more sophisticated measure of what is referred to as agricultural modernization. This is an interaction term that includes fertilizer intensity, tractor intensity, and the average years of schooling of the population. The next sets of results in Table 2 incorporate the broader definition of agricultural modernization.

Table 2
Different permutations of Equation (3) with a broader version of agricultural modernization

Independent variable:	1	2	3	4	5	6	7	8
lnGDP60	-004**	-0.007**	0'-0.009**	-0.01**	-0.01**	-0.008**	-0.009**	-0.02**
t-stat	*(-2.04)*	*(-3.45)*	*(-4.29)*	*(-5.13)*	*(-4.22)*	*(-4.17)*	*(-3.42)*	*(-3.8)*
AgModern	0.001**	0.0004**	0.0004**	0.0003**	0.0003**	0.0003**	0.0003**	0.0003**
t-stat	*(5.83)*	*(3.7)*	*(2.98)*	*(2.81)*	*(3.38)*	*(3.53)*	*(3.22)*	*(3.04)*
lnInv6095		0.01**	0.02**	0.01**	0.009**	0.01**	0.008*	0.004
t-stat		*(3.86)*	*(4.52)*	*(4.35)*	*(3.48)*	*(3.61)*	*(1.94)*	*(0.92)*
Open6095			-6.56E-05	-6.06E-05	-2.10E-05	-2.45E-05	-2.33E-05	-1.02E-05
t-stat			*('-0.89)*	*(-1.06)*	*(-0.37)*	*('-0.36)*	*(-0.36)*	*('-0.21)*
ICRGE80				0.003**	0.002**			0.004**
t-stat				*(3.78)*	*(2.66)*			*(2.7)*
Statehist					0.03**	0.03**	0.02**	0.02**
t-stat					*(4.6)*	*(5.02)*	*(2.16)*	*(2.26)*
EA							0.0002	-0.001
t-stat							*(0.04)*	*(-0.26)*
LatA							-0.01**	-0.004
t-stat							*(-2.02)*	*(-0.87)*
MENA							-0.005	0.003
t-stat							*(-0.77)*	*(0.64)*
SSA							-0.02	-0.02**
t-stat							*(-1.61)*	*(-2.2)*
SA							-0.01	-0.01
t-stat							*(-1.25)*	*(-1.38)*
WE							-0.003	-0.005
t-stat							*(-0.5)*	*('-0.89)*
N	89	89	89	89	89	89	89	89
DW	1.93	1.71	1.98	2.28	2.25	2.22	1.78	1.97
R square	0.31	0.47	0.49	0.57	0.68	0.63	0.69	0.76

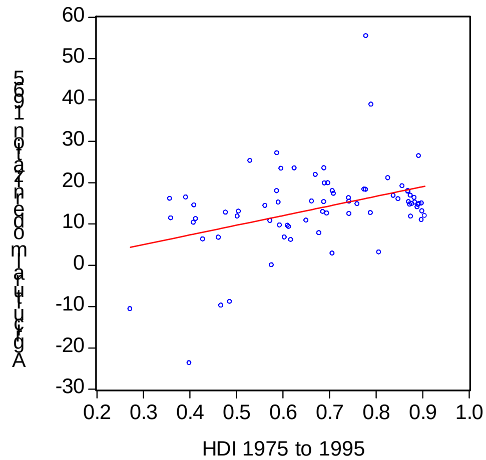
Note: Dependent variable: per capita GDP growth from 1960 to 1995; a constant term is included in each equation but not reported here; * represents statistical significance at 90% and ** represents statistical significance at 95%

Table 2 shows that the results do not change significantly when a more sophisticated measure of agricultural productivity or agricultural modernization is incorporated into the estimations. The above table has fewer equations compared to Table 1 because the *School* variable was removed from the analysis since a measure of schooling in 1960 was included in the agricultural modernization term. Some different permutations of variables are also carried out to make certain that the results are not suffering from mculticollinearity bias. Once the institutional quality variable is introduced the Durbin Watson values suddenly jump in value. Therefore equation (5) is re-estimated without the institutional quality variable in (6). The results are not seen to change significantly. Moreover, the final equation is also estimated without the institutional quality variable in (7) and again, as before, results are found to be quite consistent with previous specifications. The results from the above estimations show that agricultural modernization in early 1960's was a necessary precondition for economic growth in the next two decades. It is seen that the countries in the sample converge in growth rates once the agricultural modernization is used as a conditioning variable. The results also show that these results remain unaffected when other variables such as investment share, openness, state antiquity, institutional quality and various regional dummies are introduced. Among the other variables, there is strong evidence of state antiquity and institutional quality as having a positive impact on growth. The evidence for the impact of investment share on per capita GDP growth is not as strong as the others. Among the regional dummies Sub-Saharan Africa is found to have a significant negative impact on growth.

Overall, the results in both Table 1 and Table 2 point to the importance of agricultural productivity or agricultural modernization as a precondition for future economic growth. The results also show that agricultural modernization in the early 1960's had a strong and positive impact on economic growth that followed. The results in Table 2, show that, similar to the implications of Table 1, openness to trade was not an important factor for economic growth for the sample of countries.

The next step in the analysis is to shift focus to a broader definition of development and to see how far agricultural modernization has affected the general wellbeing of a country. So far the focus had been on factors that have an impact on economic growth. Now the analysis moves on to test how much impact agricultural modernization might have had on human development itself. As mentioned in the previous section, recent literature has found significant connections between the agricultural sector and poverty reduction, increases in social welfare or reduction in morbidity, etc. These measures of well-being are perhaps best captured by the levels of human development as measured by the Human Development Index (HDI) by the UNDP. In order to get an intuitive sense of the relationship, Figure 4 plots the relation between HDI in 1975 to 1995 and Agricultural modernization in 1965.

Figure 4



The figure shows that there is a positive relation between agricultural modernization in 1965 and human well-being from 1975 to 1995.

In order to analyze this relationship between level of human welfare or development and agricultural modernization, the next set of results are based on estimates of Equation (4), but the other control variables are gradually included into the equation to test for the robustness of the critical variable. One of the first things to be noted from the table of results is the smaller sample size, which shrinks from 89 to 78 due to unavailability of data on HDI. Since there are fewer variable being regressed (refer to footnote 1) on the HDI measure, there are fewer equations being reported above. In a number of ways these results echo the results for economic growth presented in Table 2. These show that agricultural modernization is a necessary precondition for improved well-being. The results for agricultural modernization are statistically significant at 95% for all the equations except the last one, where the significance level drops to 90%. An important and interesting difference between the above results and those of Table 2 is that the variable measuring state antiquity, which was found to have a significant impact on economic growth, is no longer significant. Yet another interesting difference is the impact of the openness variable.

The results of Table 1 and Table 2 showed that openness was not a significant factor for economic growth, but the above results show that openness, if anything, had a significant negative impact on well-being for the period under consideration. In terms of the regional dummies, Sub-Saharan Africa and South Asia are found to have significant negative impacts on overall well-being as well. However, the share of investment in GDP and institutional quality, along with agricultural modernization, are found to be robust and have a significant and positive impact on human well-being as well as economic growth.

Table 3
Different permutations of Equation (4)

Independent variable:	1	2	3	4	5	6
AgModern	0.007**	0.004**	0.004**	0.003**	0.004**	0.003*
t-stat	*(4.18)*	*(2.71)*	*(2.56)*	*(2.54)*	*(2.98)*	*(1.89)*
lnInv6095		0.2**	0.2**	0.15**	0.15**	0.08**
t-stat		*(5.37)*	*(5.21)*	*(4.09)*	*(4.22)*	*(2.59)*
Open6095			-0.001**	-0.001**	-0.001**	-0.0003*
t-stat			*(3.45)*	*(2.31)*	*(2.73)*	*(1.83)*
ICRGE80				0.03**	0.03**	0.03**
t-stat				*(3.89)*	*(4.04)*	*(3.91)*
Statehist					-0.08	-0.08
t-stat					*(-1.66)*	*(-1.44)*
EA						-0.06
t-stat						*(-1.47)*
LatA						0.01
t-stat						*(0.36)*
MENA						-0.006
t-stat						*(-0.13)*
SSA						-0.17**
t-stat						*(-3.59)*
SA						-0.18**
t-stat						*(4.07)*
WE						0.05
t-stat						*(1.46)*
N	78	78	78	78	78	78
DW	2.02	1.99	2.14	2.32	2.33	2.47
R square	0.15	0.57	0.64	0.71	0.72	0.87

Note: Dependent variable: per capita GDP growth from 1960 to 1995; a constant term is included in each equation but not reported here; * represents statistical significance at 90% and ** represents statistical significance at 95%

The results presented in the figures and tables point to the importance of agricultural modernization as a precondition for both economic growth and general well-being of the population. The paper had begun by asking the following questions. First, does absolute economic convergence occur and, if not, is convergence conditional upon agricultural productivity? In other words, is increased agricultural productivity a condition for economic convergence? Second, if so, is the modernization of agriculture an important determinant of overall growth? Is this effect robust to the inclusion of other variables? Third, given the non-traditional roles for agriculture, does agricultural modernization have a significant impact on human development? Is this impact robust to the inclusion of other variables? Now these can be answered. To answer the first question – yes, conditional convergence is found when the sample is controlled for agricultural precondition. Thus, according to the results of this paper, agricultural productivity or agricultural modernization is a condition for economic convergence between countries' growth rates. To answer the second question – yes, modernization of agriculture is an important determinant of overall growth. To answer the third question – yes, it is robust to the inclusion of other variables. The answer to the last questions is also yes, agricultural modernization does have a significant impact on human development and this relationship, like the previous ones, is robust to the inclusion of other variables.

IV

In theorizing about long-run growth and development agriculture seemed to disappear from the literature and ceased to play an important role after the development of dualistic models in the 1950s and 1960s. However, recently there has been a re-emergence of interest and a reconsideration of the importance of agriculture in the development process with a number of models being constructed which incorporate agriculture. These models and the theories they propose find agriculture to play a critical role in long-run growth and development.

An empirical analysis of agriculture's role in economic growth and development was undertaken in this paper. Specially, this paper analyzes the importance of a modernized agricultural sector to economic growth and development. Agricultural modernization, as applied to this paper, is defined in a simple as well as a complex manner. In its simple form it is measured by the intensity of fertilizer usage per hectare of land. In its more complex measure it includes improved technology which is a product of a measure of fertilizer intensity as well as tractor intensity along with a more educated population. The idea is that increased technology in agriculture would increase agricultural productivity or value-added in agriculture while freeing up resources which could be used for other productive uses. The reason for including a measure of education is that an educated population adds to the overall human capital which thereby adds to the proportion of human capital that can be allocated towards achieving further technological progress in agriculture. The results indicate that the modernization of the agricultural sector is not only a significant precondition to achieving economic growth but that agricultural modernization itself has had a significant positive impact on economic growth as well as in improving economic well-being. The implication then is that policy aimed at achieving higher growth rates should be aimed at improving agricultural productivity via investment in that sector.

Footnotes

[1] It needs to be mentioned here that the agricultural modernization variable (*AgModern*) is slightly different from the version used in Table 2. The education component of *AgModern* was excluded from the specification since a measure of education is included in the HDI. Similarly the log of per capita GDP in 1960 is no longer included since the HDI includes a measure of per capita GDP within itself. Including either log of per capita GDP in 1960 (or 1975) and a measure of schooling would increase the risks associated with multicollinearity.

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