Agriculture Productivity Growth: Is the Current Trend on the Track to Poverty Reduction?

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Abstract

In this study we evaluate the effect of annual productivity growth in agriculture over the 1991-2001 period on poverty in eleven developing countries. We compare this with the optimal pattern of productivity growth of comparable cost with the sole goal of maximizing poverty reduction. This comparison reveals that regional agricultural development is a viable option in the fight for poverty reduction.

1. Introduction

The contribution of agriculture growth to economic development in developing countries has been under examination for several decades and has recently received greater attention by policy makers due to its potential for poverty reduction[1]. Agriculture productivity growth may have more immediate multiplier effects in improving the well-being of the majority of the poor due to the fact that most of the world's poor households reside in rural areas, and agriculture comprises the largest component of the rural economy in most developing countries (The World Bank, 2000). This conjecture is supported by the coincidence of agricultural productivity growth with declining poverty rates in Asia and the increase in poverty in Sub-Saharan Africa following a decade of slow agriculture productivity growth.

The empirical evidence on the relationship between technical change in agriculture and poverty supports the proposition that the distribution of benefits from increased agricultural production will bring about reductions in rural poverty (Lipton and Ravallion, 1993). Technological change in agriculture can alleviate poverty both directly by raising the welfare of poor farmers who adopt the innovation, as well as indirectly through the effects on the price of food for net buyers, and labor effects in agriculture. The relative magnitude of these effects on poverty can be quantified through computable

[1] In 2003, several international organizations, including the World Health Organization (WHO), the United Nations Environment Program (UNEP), the Food and Agriculture Organization (FAO), the United Nations Development Program (UNDP) and the World Bank decided to join forces following up on the recommendations developed by a seven-month-long multi-stakeholder international consultation on Agricultural Science and Technology.

general equilibrium (CGE) models due to their ability to capture the changes in production and consumption, as well as welfare of households (Saudolet and de Janvry, 1992). However, most of the attempts to measure the impact of productivity growth on poverty using CGE models have lacked an historical context and have also failed to bring to bear actual survey data.

In the single country level, one relevant study is Coxhead and Warr (1995)'s which uses a general equilibrium model to explicitly account for the earnings profile of households across the income distribution. They underscore the critical role of factor markets in determining the poverty impact of technological changes in the Philippines, finding that two thirds of the poverty reduction is transmitted through the factor markets.

Cranfield et. al. (2002) assess *ex post* the distributional consequences of technical change by combining three international databases: the International Comparisons Project (ICP) data on consumption, the Deninger and Squire data on income distribution, and the Global Trade Analysis Project (GTAP) database on global trade and production. Their study extends the detail country case study approach offered by Coxhead and Warr. They propose a framework, in the absence of household budget and income shares, to evaluate the differential impact of technical progress, both across sectors and across countries. Their method is appealing, and under the stated data limitations, it may be acceptable as a first approximation of the relationship between technology and poverty.

The main contribution of our study is to assess poverty reduction caused by agricultural growth in developing countries, and to identify at a sectoral level what patterns of productivity growth in agriculture might be more efficient in lifting the poor out of poverty. In particular, this paper supersedes previous studies by incorporating two previously unavailable data sets into its general equilibrium framework: productivity growth in agricultural production estimated on historically observed changes in total factor productivity, and detailed factor shares information obtained from national household surveys. The changes in income and prices resulting from this growth, and calculated in the global model, are then combined with a micro-simulation analysis of household level impacts, providing an assessment of poverty changes. The second improvement is the identification of agricultural productivity growth, equivalent to the costs implied by the growth projections, which would be optimal in the capacity of poverty reduction. This exercise lends itself to draw conclusions whether changing the current agricultural growth into a different direction could lead to a significant reduction in poverty.

2. Methodology

In this work, we decide whether changing the historical pattern of growth in agriculture could lead to greater poverty reduction. A straightforward way of answering this is to measure how much poverty reduction is due to the present growth and compare this number to the greatest possible poverty reduction attainable with a different pattern of growth of comparable cost. If we found the difference to be significant, we could give an affirmative answer and list an alternative set of growths in agricultural sectors that would lead to a greater poverty reduction; otherwise we would confirm that the historical growth pattern in agriculture is indeed the best possible in terms of poverty reductions and need not be changed. In line of this thought, we perform two exercises: in the first one, we measure the annual poverty change due to the historical agricultural growth for our sample of eleven developing countries; in the second exercise, we perform an optimization that minimizes poverty for an alternative set of growths in agricultural sectors subject to the total average growth being equal to that determined historically (see Figure 1 for a graphical exposition of our approach). Each exercise yields a set of poverty changes that we report and use as a basis for our conclusions. We describe each exercise in greater detail below.

2.1 Measuring poverty change associated with historical growth rates

We measure poverty change as a result of price and income changes by applying a microlevel household model using the following three-step method: in the first step, we identify the poverty level of income that corresponds to the reported level of poverty. In this work we take poverty estimates from Ross-Larson and de Coquereaumont, (2001) as the share of population that is believed to live on less that one dollar a day. In the second step, we use the AIDADS demand system (Rimmer and Powell, 1992) estimated by (Cranfield *et al.*, 2003) to calculate a level of utility associated with the poverty level of income. We take this utility as an anchored definition of poverty that remains invariable to the changes in consumer prices or household incomes. Productivity growth is modeled into a global computable general equilibrium model in order to obtain price and income changes. In the last step, we update all prices and incomes following the results of our global model and count the number of households whose utility lies below that associated with poverty.

2.1.1 Estimates of productivity growth

We estimate the average annual productivity growth in crops and livestock from 1991 to 2001, using a directional Malmquist Index, following Nin Pratt et.al.'s methodology (2003). These estimates are used as inputs into the global CGE model to simulate productivity growth in the production of crops and livestock by assuming a neutral technological improvement. Table 1 shows the calculated annual productivity rates for our focus countries. We can see that livestock production on average has experienced a higher growth than crops during the covered period. Notable cases are Colombia and Mexico which has seen a more pronounced growth in livestock production. Peru and Chile however, have experienced a more pronounced growth in their crops sector. If we take this productivity growth as evidence of a continuous trend, the annual average for livestock of 2.92 is consistent with Delgado et. al.'s (1999) prediction of developing world total production annual growth rate of 3.0% and 2.8% for poultry and pork for the period 1993-2020.

2.1.2 GTAP database and Model

This study draws on the GTAP 6 database (Dimaranan and McDougall, 2004), featuring 2001 as the benchmark year. We aggregate the sectors of production with the focus of keeping detail in main agriculture activities. Namely, we identify in agriculture: staple crops, food crops, cash crops, and livestock (see appendix for detail sector mapping).

We use the GTAP global general equilibrium model (Hertel, 1997), which allows for an exact and theoretically consistent measure of technical change and enables a detailed analysis of the impact of technical change on returns, and factor use changes.

2.2 Finding optimal growth patterns and associated poverty change

In order to derive a vector of optimal growths **a**, we define and solve a math program that incorporates our objective of maximum reduction in world poverty *K* while constraining ourselves to a budget constraint defined by the average growth rate $\bar{g}$ implied by the historical growth rates. The program can be written as $\min_{a} K = Y(\Phi(i))$, subject to $\mathbf{a}'\mathbf{w} \leq \bar{g}$ where poverty *K* is defined by a poverty function Υ(·). Function Υ(·) links the changes in prices and incomes to poverty changes and has been estimated as a second order approximation of the poverty response from our microlevel model. This function takes as its arguments the price changes defined by the price function Φ(·), which is a summary function of the global GTAP model. Price function Φ(·) takes as an argument the growth vector **a**. Finally, the sizes of agricultural sectors **w** are used to weight respective growth into average growth, which is confirmed to be no greater than that observed historically.

2.2.1 Price function: CGE link between productivity changes and global changes in prices and incomes

Our method of linking productivity changes to prices and incomes is based on expressing price and income (**p**) changes through a summary function of productivity change (**a**) based on an actual CGE model. We base our derivation of the summary function on our understanding of the model, the GTAP model in our case, of as a function that maps a vector of exogenous variables, productivity change (**a**) to a vector of endogenous ones, prices (**p**). This fact could be captured by a simple equation $\mathbf{p}=GTAP(\mathbf{a})$.

Naturally, a proper definition of this function in terms of parameters is often infeasible or perhaps impossible as this would require a lengthy back-solving exercise in which a model is reduced into a single equation. Even if a proper evaluation of this equation is not possible, its reasonable approximation can be both acceptable and useful. In our case we use the linear approximation of the percent changes in variables in the GTAP model. Under such a definition of the model, we rewrite the equation in a linear form as a product of a parameter matrix M and exogenous variables as $\hat{\mathbf{p}}=M\times\mathbf{a}$. This equation has no intercept, because in the percentage change, linear form of the model we require that a zero endogenous and exogenous change be a solution of the model, i.e. $\mathbf{0}=M\times\mathbf{0}$.

2.2.2 Poverty function: Econometric model of poverty change

Because discreet optimization is still difficult to perform in the year 2005, we replace a proper poverty calculation based on the real data with an estimated poverty function $\Upsilon(\cdot)$ that simply maps changes in prices changes in poverty K as $K=\Upsilon(\mathbf{p})$. The estimation is based on detailed data on factor earnings contained in household surveys as reported by Ivanic (2002). Because of the relative nature of both poverty and prices, the poverty function is estimated as a second order approximation of the percent change form $\hat{K}=\sum_i \alpha_i \hat{p}_i+\sum_i \beta_{ij} \hat{p}_i^2$. Because a homogeneous change in all prices should produce no change in poverty, we impose the following homogeneity restrictions on the parameters: $\sum_i \alpha_i=0$ and $\sum_i \beta_i=0$.

We estimate this function for six prices and five incomes (factor prices) as used in the work of Hertel *et al.* (2003) on trade liberalization and poverty. The included goods are: grains, livestock, other food, durables, non-durables, and services. On the income side we include the returns to the following factors: land, capital, unskilled labor, skilled labor and transfers.

To estimate this regression, we have created a random sample of 60,000 observations of changes in prices and incomes drawn randomly from a uniform distribution. We have deflated these prices by CPI change implied by them and fed them into a household model to calculate poverty changes based on observed income distributions and an AIDADS consumer demand system based on the work of Rimmer and Powell (1992). This demand system was calibrated to each of the eleven countries included in our household model based on the work of Cranfield *et al.* (2003). The representation of the consumption behavior in the household model by a demand system is not crucial to our framework, but a result of the unavailability of expenditure data in the household surveys. If a new set of household surveys contains enough detail in consumption, this demand forecasting could be avoided.

3. Results

Our results illustrate not only how poverty is annually reduced by agricultural productivity growth, but also the maximum possible reduction in poverty that could be achieved by altering the pattern of growth.

3.1 Reduction in poverty due to annual agricultural productivity growth

Our focus is to identify the effect of agricultural productivity growth on poverty. Following our methodology we translate the annual average growth rate into poverty changes. Our results (Table 2) show that annual productivity growth in agriculture has a positive effect in reduction poverty across all of the developing countries used in our study. This is in line with previous empirical studies which associate agricultural productivity improvements with a reduction in poverty. The results are varied, for instance, Bangladesh shows that agricultural growth can lift a sizable amount of people out of poverty. On the other hand, Chile shows that there is no an appreciable gain in poverty reduction by expanding agricultural activities.

Analyzing these changes, we can focus on households' income specialization to assess which households benefit the most from the productivity changes. As shown by Hertel *et. al*. (2003), specialized earnings source are of relevant importance in the analysis of poverty impacts of trade liberalization. We follow this stratification of income for the analysis of productivity and poverty, because in general households will be affected by changes in prices and income to the extent of their reliance on sectors specific factors of production.

Table 3 shows the percentage change in poverty rates by specialized income source. We can observe that in Bangladesh the greater changes in poverty rates do not occur directly in agriculture self-employed households, but for households who are self-employed and not related to agriculture, and for urban households with diverse sources of income (non-specialized). However, the benefits to the rural Bangladesh's economy are evidenced by the relative changes in both the rural not self employed household and the rural diverse household.

3.2 Extra gains in Poverty Reduction by selecting an optimal pattern of productivity growth

By reallocating the implied cost reductions associated with historical technical change, we are able to show how many more people could be lifted out of poverty by redirecting, or in some cases intensifying productivity growth in agricultural sectors. In Table 4, we can see in column 2 the change in poverty headcount due to optimal productivity growth, and column 3 shows the relative improvement. We find some striking results: on one end it may seem that the historical productivity trend is on the right track in Bangladesh (as evidenced by the small gain in the optimal case), while much more poverty reduction may be achieved in Mexico, Philippines and Venezuela by redirecting productivity growth in different sectors. This information combined with the sectoral optimal allocation shown in Table 5 provides a complete overview of how shifting resources to more efficient uses can help the most under the goal of extreme poverty reduction.

With the sectoral information, we can say that a more efficient poverty outcome can be obtained in Indonesia by inducing more productivity in staple crops in contrast to keeping the current trend in livestock productivity moving ahead. This country in particular offers high potential in the fight against poverty if South Asian regional productivity crops level could be attained. Thailand is an example of how shifting productivity to food crops could yield an improvement of 21% in poverty reduction with respect to the historical average annual agricultural productivity. In South America, we find that Brazil could do better if productivity growth were focused on staple crops, while Chile and Peru would do better in poverty reduction if crops productivity were concentrated on cash crops.

As shown, the framework used in this study allows identifying the poverty reduction effect due to annual productivity growth, and it provides a useful comparison with an equivalent cost reduction option which maximizes poverty reduction, quantify the potential gains in number of people lifted out of poverty and in relative terms.

4. Conclusions

In this work, we have shown that the historically observed annual growth in agricultural productivity has a positive effect on poverty reduction for all of the eleven developing countries used in our sample. Nonetheless, using our framework we have also shown that this growth could be redirected into different production sectors in agriculture for additional poverty reduction in the range from 4 percent in Bangladesh to 59 percent in

Indonesia. We may therefore conclude, that changing the momentum of the historical trend in the growth of productivity in agriculture, could be a viable instrument in the fight against poverty.

Our results are substantiated with good data on the predictions in agricultural productivity growth and household income composition. Thus we may feel fairly comfortable with both the initial perturbations to the model that result in price changes, and the poverty results obtained as the results of these changes.

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Table 1. Average Annual Productivity Growth (1991-2001).

	Crops	Livestock
Bangladesh	2.98	3.28
Indonesia	0.31	1.72
Philippines	0.37	2.09
Zambia	0.88	4.29
Brazil	3.15	2.78
Chile	2.77	0.56
Colombia	1.71	4.71
Mexico	0.99	4.82
Peru	5.28	1.50
Thailand	1.32	2.09
Venezuela	2.57	4.29

Source: authors' calculations using FAO data

Table 2. Effect on Poverty of Agricultural Productivity Growth

	Percentage Change in poverty rates	Change in poverty headcount in thousands
Bangladesh	-4.52	-1,737
Brazil	-1.65	-145
Chile	-0.59	-4
Colombia	-0.72	-61
Indonesia	-0.15	-48
Mexico	-0.58	-93
Thailand	-1.13	-14
Peru	-0.71	-29
Philippines	-1.35	-134
Venezuela	-1.07	-61
Zambia	-0.41	-30

Source: authors' calculations

Table 3. Percentage change in poverty rates by specialized income source

	Bangladesh	Chile
Agriculture	-4.3	-0.5
Non Agriculture	-7.3	-0.9
Urban – wage dependent	-4.5	-0.8
Rural – not self employed	-2.6	-0.6
Transfers	-0.9	-0.1
Urban diverse	-7.0	-0.9
Rural diverse	-4.7	-1.0

Source: authors' calculations

Table 4 . Effect on Poverty of Agricultural Productivity Growth: Improvement in poverty reduction due to adopting optimal productivity.

	Historical Observed Productivity Growth	**Optimal Productivity**	**Improvement in poverty reduction due to adopting optimal productivity**
	change in poverty headcount in thousands		in percentage
Bangladesh	-1737	-1812	4.32
Brazil	-145	-171	17.92
Chile	-4	-5	26.32
Colombia	-61	-76	24.69
Indonesia	-48	-76	59.46
Mexico	-93	-121	30.09
Thailand	-14	-17	21.15
Peru	-29	-33	13.99
Philippines	-134	-210	56.72
Venezuela	-61	-89	46.06
Zambia	-30	-33	9.85

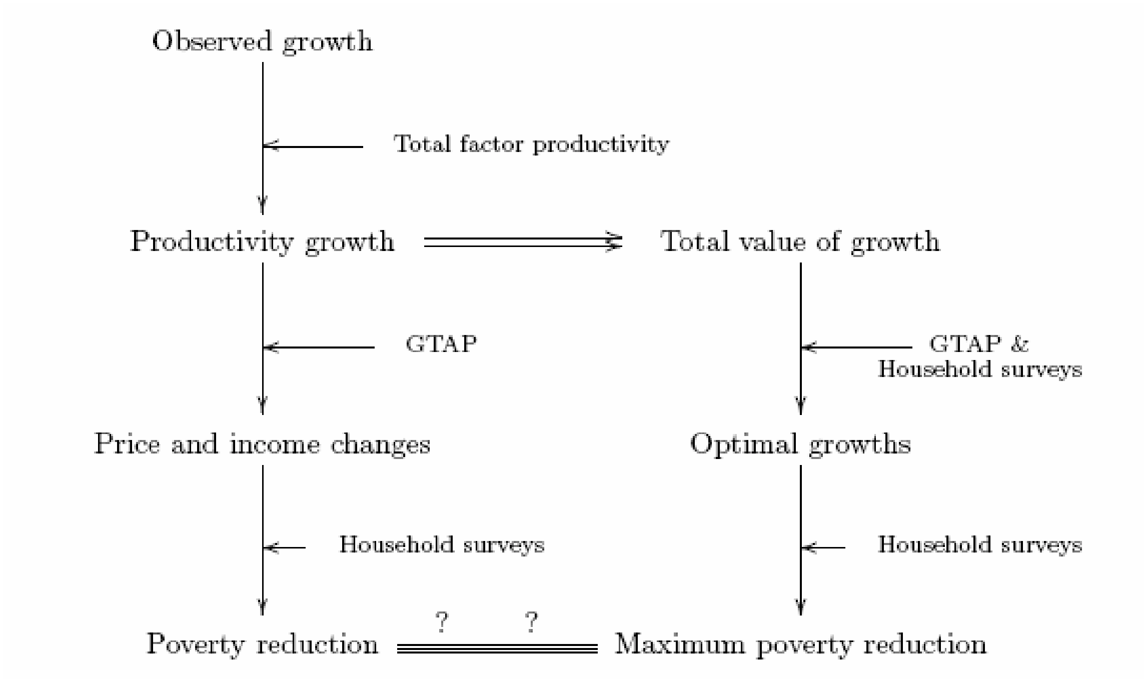
Source: authors' calculations

Table 5. Sectoral Distribution of Optimal Productivity Growth

	Staple Crops	Food Crops	Cash Crops	Livestock
Bangladesh	4.82	2.01	3.78	0.74
Indonesia	2.93	0	0	0
Philippines	3.24	0	4.61	0
Zambia	0.79	1.74	1.53	2.89
Brazil	7.37	0	0.01	5.49
Chile	3.14	0	8.94	1.86
Colombia	8.53	0	4.36	3.55
Mexico	4.68	1.08	2.68	1.88
Peru	3.72	0	8.87	1.47
Thailand	0.00	5.76	0	1.15
Venezuela	2.31	0	25.45	0

Source: authors' calculations

Figure 1. Scheme of the approach



Appendix . Sectoral aggregation

GTAP sector	Description	New Sector
pdr	Paddy rice	Staples Crops
wht	Wheat	Staples Crops
gro	Cereal grains	Staples Crops
v_f	Vegetables, fruit, nuts	Food Crops
osd	Oil seeds	Food Crops
c_b	Sugar cane, sugar beets	Cash Crops
pfb	Plant-based fibers	Cash Crops
ocr	Crops nec	Cash Crops
ctl	Cattle,sheep,goats,horses	Livestock
oap	Animal products	Livestock
rmk	Raw milk	Livestock
wol	Wool, silk-worm cocoons	Livestock
frs	Forestry	Cash Crops
fsh	Fishing	Livestock
coa	Coal	Non durables
oil	Oil	Non durables
gas	Gas	Non durables
omn	Minerals nec	Non durables
cmt	Meat: cattle,sheep,goats,horse	Livestock Processed
omt	Meat products	Livestock Processed
vol	Vegetable oils	Other Food Processed
mil	Dairy products	Livestock Processed
pcr	Processed rice	Other Food Processed
sgr	Sugar	Other Food Processed
ofd	Food products	Other Food Processed
b_t	Beverages and tobacco	Other Food Processed
tex	Textiles	Non durables
wap	Wearing apparel	Non durables
lea	Leather products	Non durables
lum	Wood products	Non durables
ppp	Paper products, publishing	Non durables
p_c	Petroleum, coal products	Non durables
crp	Chemical,rubber,plastic prods	Non durables
nmm	Mineral products	Non durables
i_s	Ferrous metals	Durables
nfm	Metals nec	Durables
fmp	Metal products	Durables
mvh	Motor products vehicles and parts	Durables
otn	Transport equipment	Durables
ele	Electronic equipment	Durables
ome	Machinery and equipment nec	Durables
omf	Manufactures nec	Durables
ely	Electricity	Services
gdt	Gas manufacture, distribution	Services
wtr	Water	Services

Appendix cont.. Sectoral aggregation

cns	Construction	Services
trd	Trade	Services
otp	Transport nec	Services
wtp	Sea transport	Services
atp	Air transport	Services
cmn	Communication	Services
ofi	Financial services nec	Services
isr	Insurance	Services
obs	Business services nec	Services
ros	Recreation and other services	Services
osg	PubAdmin/Defence/Health/Educat	Services
dwe	Dwellings	Services