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Poverty Impacts of Improved Agricultural Productivity: Opportunities for Genetically Modified Crops

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Constraints on land and water resources, growth in population, and an apparent slowdown in agricultural productivity raise concerns that food prices may rise substantially in the coming decades. A key question is whether policies aimed at increasing agricultural productivity may be effective in reversing the long-run trend and bringing about significant reductions in food prices. This article uses a global general equilibrium model and a set of microeconomic household models for a sample of 26 developing countries to assess potential implications of higher agricultural productivity—such as through the adoption of genetically modified plants—for household incomes, farmer profits, and poverty. Higher agricultural productivity resulting from increased investments in research and development is found capable of significantly lowering poverty by lowering the cost of consumption of the poorest households without significantly hurting farmers' returns. We also found that raising agricultural productivity among the developing countries only is sufficient to achieve most poverty reduction in the global scenario.

Key words*:* agriculture, productivity.

Introduction

There is widespread concern that food prices may rise substantially in the coming decades due to a combination of increasing population, binding land and water constraints, potential increases in demand for biofuels, and climate change (Evans, 2009; Fischer, Byerlee, & Edmeades, 2009; Msangi & Rosegrant, 2009). As shown by van der Mensbrugghe, Osorio-Rodarte, Burns, and Baffes (2009), these factors could result in substantial increases in food prices, with potentially adverse implications for poverty (Ivanic & Martin, 2008).

The upward pressure on food prices makes it particularly important to focus on the potential for increasing productivity. Productivity improvements—particularly in developing countries—have been found to be a powerful force for poverty reduction (Datt & Ravallion, 1998; de Janvry & Sadoulet, 2002). The recent spread of genetically modified plants in developing countries has often resulted in significantly higher yields and lower input use, for example in the case of cotton (Qaim & Zilberman, 2003) and maize (Gouse, Pray, Schimmelpfennig, & Kirsten, 2006). Informed commentators also believe that there are scientific possibilities for substantial further increases in productivity (Fischer et al., 2009). There is also strong evidence of serious underinvestment in research on agricultural productivity, as evidenced by very high rates of return on government investments in research and development (Alston, Marra, Pardey, & Wyatt, 2000).

The impact of agricultural productivity on poverty has historically been a source of controversy. Higher productivity can be expected to lower food prices—either at a national or global level, depending upon whether countries are open to trade in agricultural products. And such declines in prices can be expected to benefit consumers not involved in farming, and particularly the poorest, who spend around three-quarters of their income on staple foods (Cranfield, Preckel, & Hertel, 2007). If the decline in agricultural prices is sufficiently large, the increase in farm incomes may be small (Irz, Lin, Thirtle, & Wiggins, 2001) or even negative.

In this article, we address the potential poverty-reducing role of policies such as agricultural research and development that raise agricultural productivity. Specifically, we explore a policy of increased investment in agricultural research and development that leads to increases of one percentage point annually in agricultural productivity growth over the 40 years to 2050. Using a global macroeconomic model and a set of microeconomic models, we quantify the likely impacts of the projected global growth on world food prices and poverty. Next, we describe the model used for the analysis. Then, we formulate and discuss the scenarios used and follow that with the results.

Table 1. Overview of the agricultural and food sectors considered in this study (original GTAP sector in parentheses).

Rice (PDR, PCR)	Other oil seeds (OSD)	Other animal products (OAP)	Other meat (OMT)
Wheat (WHT)	Peanuts (OSD)	Eggs (OAP	Poultry meat (OMT)
Other grains (GRO)	Soybeans (OSD)	Poultry (OAP)	Pork (OMT)
Maize (GRO)	Sugar beets and sugar cane (C_B)	Swine (OAP)	Oils and fats (VOL)
Sorghum (GRO)	Plant-based fibers (PFB)	Raw milk (RMK)	Milk (MLK)
Cassava (V_F)	Other crops (OCR)	Wool (WOL)	Sugar (SGR)
Plantains (V_F)	Cofee and tea (OCR)	Forestry (FRS)	Other food (OFD)
Potatoes (V_F)	Tobaco (OCR)	Fishing (FSH)	Beverages and tobacco (B_T)
Other vegetables (V_F)	Other bovines (CTL)	Other bovine meat (CMT)	
Other fruits (V_F)	Cattle (CTL)	Cattle meat (CMT)	

Model

Our global simulation is based on the latest Global Trade Analysis Project (GTAP) dataset (Version 7, Prerelease 5) that describes the state of the world economy in 2004, including the levels of output, trade flows, and protection for 57 commodities. We carry out our analysis using the latest GTAP model (Hertel, 1997; http://www.gtap.org). To simplify the computations, we aggregated 34 non-agricultural and non-food GTAP commodities into four broad groups relevant for this work: energy, non-durables, durables, and services. We preserved all food-related GTAP sectors in the global model and split some important sectors into additional sectors using Food and Agriculture Organization (FAO) data on production, prices, and trade, and the recently developed MSplitCom software by Mark Horridge. An overview of this split is presented in Table 1.

Because our simulations relate to long-term changes in productivity, we consider a long-run closure that allows complete flexibility of employment of capital and labor with the necessarily-limited flexibility of land use between sectors. Because of our long-run focus, we also double the standard GTAP elasticities governing the level of substitution between imports. Increases in productivity of a particular good have different impacts on its domestic consumer price depending upon the share of the good exported (which influences the total elasticity of demand for the domestic product) and the share of imports in domestic use of the good (which influences the impact of a decline in the price of imports on the average consumer price of that good).

Poverty Assessment Model

Our poverty assessment model is based on the household survey datasets collected at the World Bank for a range of developing countries. These surveys allow us to observe consumption, production, and input use choices of individual households. We use the household surveys from 26 developing countries that span the developing world. Our sample includes seven African countries (Côte d'Ivoire, Malawi, Niger, Nigeria, Rwanda, Uganda, and Zambia), nine South and Southeast Asian countries (Bangladesh, Cambodia, Indonesia, Nepal, Pakistan, Sri Lanka, Timor-Leste, Vietnam, and Yemen), six countries from Latin America (Belize, Ecuador, Guatemala, Nicaragua, Panama, and Peru) and four in Europe and Central Asia (Albania, Armenia, Mongolia, and Tajikistan). All of the surveys used in this study are relatively recent (see Table 2) and contain detailed information on the patterns of household incomes and expenditures.

From our survey data, we obtain information on the annual expenditures and incomes of the households, revenues, and costs of any family-operated business, as well as the household size. The information on household consumption, including any own-produced consumption, was separated into eight broad categories: agricultural (food) products, non-durables, energy goods, durables, services, financial expenses, taxes, and remittances paid by the household. Agricultural products were further divided into 39 individual commodities listed in Table 1. These individual commodities roughly follow the GTAP commodity classification with some additional crops—such as sorghum, cassava, potatoes, coffee, and tea—that are likely to be particularly important to the poor in some regions. In addition to income obtained from the sales of goods and services, household incomes were also differentiated into wage income, financial income, transfers and remittances received by the household. The revenues and costs of any family-operated business were similarly classified using the same categories (i.e., agricultural sales by product, labor expenses, energy consumption, etc.).

Household demands were calibrated using CDE[1] preferences to be consistent with those in the macro

Table 2. Household surveys included in this work.

Country (1)	Survey name (2)	Year (3)	Number of households (4)	Number of people (5)	Rural households (6)	Poverty rate (7)	Rural poverty rate (8)
Albania	Living Standards Measurement Survey	2005	1,671	4,814	1,447	0.8	0.9
Armenia	Integrated Survey of Living Standards	2005	6,815	28,502	1,728	10.6	14.5
Bangladesh	Household Income-Expenditure Survey	2000	7,440	38,518	5,040	40.2	46.1
Belize	Household Income and Expenditure Survey	2009	1,546	6,794	731	33.5	38.4
Cambodia	Household Socio-economic Survey	2003	14,984	74,719	11,990	50.5	59.7
Cote d'Ivoire	Enquete Niveau de Vie des Menages	2002	10,798	57,906	5,819	23.3	29.3
Ecuador	Encuesta Condiciones de vida—Quinta Ronda	2006	13,581	55,666	5,503	15.8	27.5
Guatemala	Encuesta Nacional de Condiciones de Vida	2006	13,686	68,739	7,878	12.6	17.2
Indonesia	Indonesia Family Life Survey	2007	12,999	69,624	5,975	7.5	11.1
Malawi	Second Integrated Household Survey	2004	11,280	52,707	9,840	73.9	77.2
Mongolia	Household Income and Expenditure Survey	2002	3308	14789	1,457	22.4	23.6
Nepal	Nepal Living Standards Survey II	2002	5,071	28,099	3,655	55.1	67.0
Nicaragua	Encuesta Nacional de Hogares sore Medicion de Nivel de Vida	2005	6,619	36,642	3,356	45.1	63.6
Niger	Enquete National sur Le Budget et la Consommation des Menages	2007	4,000	28,683	2,084	65.9	83.5
Nigeria	Nigeria Living Standards Survey	2003	19,121	92,501	14,481	64.4	70.2
Pakistan	Pakistan Social and Living Standards Measurement Survey	2005	15,453	79,354	9,213	22.6	26.4
Panama	Encuesta de Niveles de Vida	2003	6362	26,434	2,944	9.4	18.2
Peru	Encuesta Nacional de Hogares	2007	22,201	95,466	8,639	7.9	17.6
Rwanda	Integrated Household Living Conditions Survey	2005	6,900	34,785	5,280	76.6	88.2
Sri Lanka	Household Income and Expenditure Survey	2007	4,633	20,290	3,478	14.0	17.4
Tajikistan	Living Standards Measurement Survey	2007	4,644	29,412	2,984	21.5	22.0
Timor-Leste	Poverty Assessment Project	2000	1,800	9,113	1,098	52.9	64.8
Uganda	Socio-Economic Survey	2005	7,425	42,220	5,726	51.5	58.3
Vietnam	Household Living Standard Survey	2004	9,188	40,438	6,938	21.4	26.4
Yemen	Household Budget Survey	2006	13,136	98,941	4,863	17.5	29.5
Zambia	Living Conditions Monitoring Survey	2002	4,166	23,074	2,090	61.9	59.4

model, while CRETH[2]/CRESH[3] structures were used to generate elasticities of supply. When productivity and prices change, we estimate the impacts on income less changes in the cost of living and recalculate the poverty headcount for each country.

Table 3. Projected changes in real food prices due to a 1% annual increase in agricultural productivity over 40 years, weighted averages for developing countries.

	Higher agricultural productivity	Higher agricultural productivity among developing countries only
Agricultural produce	-23.4	-20.3
Processed food	-26.3	-22.8
All food	-24.2	-21.0
Wages	4.3	4.5

Following Lanjouw and Ravallion (1995), we use the elasticity of the cost of living to household size equal to 0.6 to reflect economies of size in household operation, meaning that adding an additional member to a household increases the level of income required to maintain per-capita living standards less than proportionately. When the effective per-capita expenditure of a household crosses the poverty line, we account for this and update the list of households in poverty.

The poverty lines used in our calculations—reported in Column 7 of Table 2—were calculated using our household surveys in conjunction with the published poverty rates of $1.25-a-day.[4] This allowed us to identify the effective per-capita expenditure level of the households at the poverty line and use this estimate as the poverty line throughout the study.

Scenarios

Our global policy scenario involves directing investment into agricultural research and development to an extent that results in an additional 1% increase in agricultural total factor productivity over the 40-year period we consider.[5] This 1%-per-year difference is roughly the difference between agricultural and manufacturing productivity observed by Martin and Mitra (2001, Table 1). Our benchmark can be thought of as one in which the historically superior total factor productivity (TFP) performance of the agricultural sector disappears; our 1% increase in TFP experiment can be thought of as one in which agricultural TFP returns to its historical margin over the manufacturing sector.

In order to separate the contributions of higher agricultural productivity into the categories of developing versus developed countries, in the second scenario we consider changes in agricultural productivity in developing countries alone.

Results

The macro impacts of these changes on real prices are given in Table 3. We find that a global increase in agricultural total factor productivity of 1% per year sharply reduces the prices of farm output (average reduction of 23.4%) as well as the prices of processed food (average reduction of 24.2%). These results highlight the fundamental importance of agricultural productivity growth for world food prices. In addition to lowering food prices relative to the baseline, raising global total factor productivity has a positive effect on unskilled wages (a rise of 4.3%).

The other set of columns in Table 3 examines the price impacts of higher agricultural productivity in developing countries only. The outcomes of this scenario are surprisingly similar to the previous one, suggesting that most of the benefits from raising agricultural productivity in developing countries are likely to be retained by those countries.

To understand the poverty implications of our global and developing-country policy scenarios at the household level, we use our set of household models to project the impacts of these two reforms on poverty rates in the 26 countries for which we currently have detailed, recent information from household surveys. We present the total poverty impacts in Figure 1 together with impacts through producer profits and consumer costs. It is important to emphasize that the changes in producer profits are only part of the impact on farm households, whose welfare is impacted both by changes in producer profits and reductions in their cost of living.

When only the impacts of global productivity growth on producer profits are considered (the first subfigure of Figure 1), the average poverty rate is expected to rise by 0.5 percentage points, with significant variation among countries. The reason for the differences in producer return impacts is that producers are simultaneously affected by rising factor productivity (which reduces their costs) and by declining food prices and ris-

1. *Constant Difference of Elasticity preference as discussed by Hanoch (1975).*
2. *Constant Ratio of Elasticities of Transformation, Homothetic as discussed by Vincent, Dixon, and Powell (1980).*
3. *Constant Ratio of Elasticities of Substitution, Homothetic as discussed by Hanoch (1971).*
4. *We used the PovCalNet web-based tool to obtain the latest estimates of the poverty rates at $1.25-a-day poverty line definition.*
5. *Because the factor intensity of agriculture varies by crop and by country, this experiment results in different impacts on agricultural output across countries.*

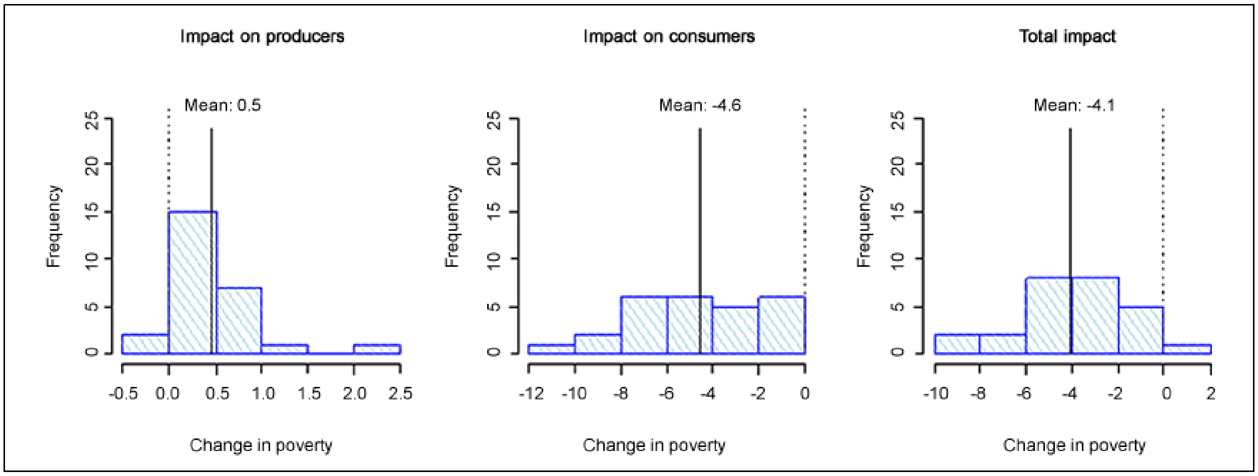

Figure 1. Distribution of changes in poverty rates due to higher agricultural productivity (relative to baseline).
Source: Authors' calculations.

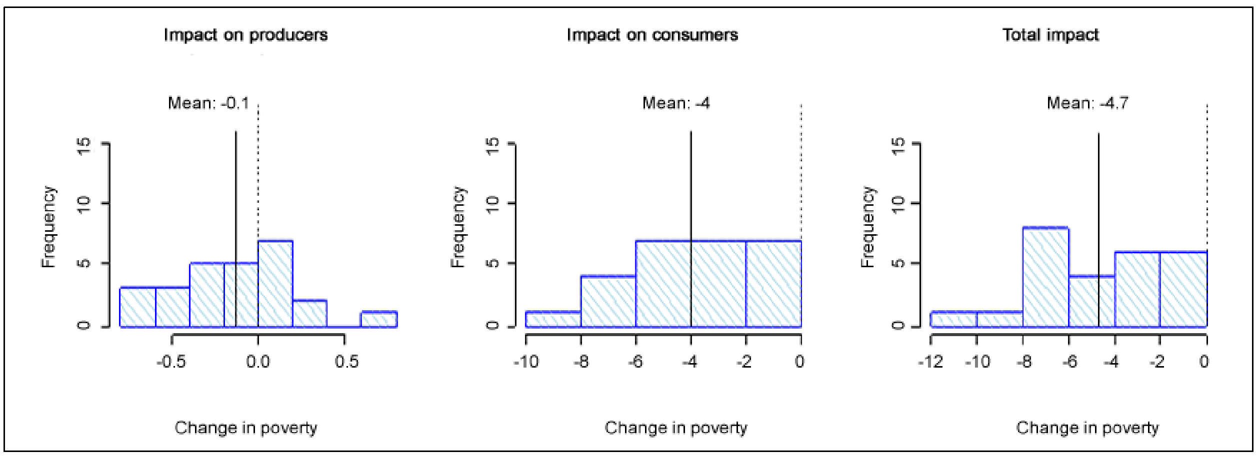

Figure 2. Distribution of changes in poverty rates due to higher agricultural productivity in developing countries (relative to baseline).
Source: Authors' calculations.

ing wages for hired labor (both of which lower their profits). While some producers, whose production is less factor-intensive, may see their revenues fall more than their costs, other producers benefit. On the other hand, consumers who face lower food prices and higher wages unambiguously benefit in this scenario (the second subfigure of Figure 1), with an average reduction in the poverty rate of 4.6 percentage points. A combination of these impacts, (shown in the third subfigure of Figure 1), show an average poverty rate reduction of 4.1 percentage points, and reductions in poverty in all but one country of the sample.

In the second scenario, we consider agricultural productivity increases that benefit only producers in developing countries. A key result of this simulation is that the average reduction in poverty of 4.7 percentage points is larger than the impact of a global increase in agricultural productivity, which means that agricultural productivity growth in developing countries is far more important for poverty reduction than that in developed countries. Another important observation is that while excluding developed countries from higher agricultural productivity has little impact on global poverty, it is better for producers in developing countries, who benefit at the expense of consumers from higher global food prices (Figure 2). These results highlight the importance for poverty reduction of increases in agricultural productivity in developing countries.

Even though our simulations have shown that higher agricultural productivity is generally beneficial for poverty reduction, they have also revealed that in exceptional cases this may not be true: a country where productivity rises less than the global or regional average may see the profits of many of its producers decline.

If these producers comprise a significant number of the poor, then it is possible that the declines in profits will not be fully offset by consumers' gains from the lower prices, resulting in an overall poverty increase.

Conclusions

In this study, we investigated the long-run impacts of higher agricultural productivity on global food prices, farm incomes, and poverty. We found that raising the agricultural TFP growth rate by one percentage point above the productivity growth of the rest of the economy is likely to significantly reduce global poverty by lowering the cost of food consumption and raising real wages, which benefit consumers in all the countries included in our sample. The impacts on farm production returns are generally small and slightly adverse for global agricultural TFP increases, with lower output prices and higher wage rates reducing profits and higher productivity raising them. The overall impacts of higher agricultural productivity are clearly positive, reducing the simple average poverty rate in our developing country sample by 4.6 percentage points from 33.8%.

Agricultural productivity gains in developing countries alone have almost as large a favorable impact on the final poverty outcomes as global increases in agricultural TFP. This finding highlights the importance of raising agricultural productivity in developing countries.

Much more work needs to be done to address the many additional questions raised by the preliminary analysis reported in this article. The results presented refer only to very broad scenarios of productivity growth across regions and commodities. Many decisions about resource allocations must be made across countries—or regions within countries—and across commodities. The analysis presented in this article is intended as only a very initial step towards addressing these important issues.

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