Promoting Global Agricultural Growth and Poverty Reduction*

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Abstract

Constraints on resources, growth in demand, and an apparent slowdown in agricultural productivity raise concerns that food prices may rise substantially over the period to 2050. One key question is how serious would be the impacts of such higher food prices on the poor. Another is how policy responses, such as increased investment into agricultural productivity or price incentives, might affect these outcomes. This paper uses a global general equilibrium model, projections of global growth and a set of microeconomic household models, to project potential implications for incomes, food production and poverty. Our baseline projections involve rising food prices whose direct effect is to increase poverty even after households have adjusted fully by increasing output and decreasing consumption. Higher agricultural productivity resulting from increased investments in research and development could offset these impacts and contribute to poverty reduction, with some regional differences: in Asia, we find that most of poverty reduction would come from real wage increases, while Latin America would benefit mainly from the reduced food prices. Increasing food self-sufficiency in developing countries by raising import barriers would generally increase poverty and hence reduce food security at the household level.

*This paper reflects the views of the authors alone and not those of the World Bank or any other institution with which they may be affiliated. Preliminary draft..

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Introduction

There is widespread concern that food prices may rise substantially in the coming decades because of a combination of increasing population, land and water constraints, increasing food demand per person; potential increases in demand for biofuels; and climate change (Evans 2009; Fischer, Byerlee and Edmeades 2009; Msangi and 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 and Martin 2008).

One response to this concern is to argue for agricultural market price support and protection as a means of stimulating output and reducing the dependence of particular countries on imported food (Taylor 2008). Another is to focus on the potential for increasing productivity as a means of raising food output without necessarily raising prices. The approach of focusing on productivity improvements—particularly in developing countries—has the potentially important benefit that it can be a powerful force for poverty reduction in developing countries (Datt and Ravallion 1998; de Janvry and Sadoulet 2002). While the evidence on a slowdown in agricultural productivity is mixed (Fuglie 2008; Alston and Pardey 2009), there is considerable evidence that total factor productivity growth in agriculture was higher than in the rest of the economy during the period of the green revolution (Martin and Mitra 2001). Informed commentators also believe that there are scientific possibilities for substantial further increases in productivity (Fischer, Byerlee and Edmeades 2009). There is also strong evidence of serious under-investment in research on agricultural productivity, as evidenced by very high rates of return on government investments in research and development (Alston and Pardey 2000).

In this paper, we try to address comprehensively the issues of the projected growth on poverty and the role of agricultural policies aimed at promoting further reduction in poverty. We first consider a baseline scenario of global growth with agricultural productivity growing at the same rate as the whole economy. Under this scenario, we examine the likely implications for poverty in developing countries of changes in incomes and food prices. We then explore a policy of increased investment in agricultural research and development that leads to increased agricultural productivity and food production. As an alternative, we examine the consequences of a protectionist policy with the aim of raising domestic agricultural prices and production. In the next section of this paper, we consider the issues of global growth, agricultural productivity and poverty in more detail. Then, we turn to the model used for the analysis. In the third section, we discuss the scenarios used, while the fourth section contains results.

Baseline projections of global growth

Considerable effort has been focused on projecting world population in the coming decades. Because population growth is likely to continue at a relatively high rate over this period, and because the impact of a one percent change in population on food demand is much higher than the impact of a one percent increase in real incomes, projections of global population are central in global projections of food demand. Some population projections, such as those prepared by the United States Census Bureau are based on careful analysis of drivers of population growth such as fertility, migration and mortality (Mulder, 2002).

Increases in consumer incomes—especially for relatively poor consumers whose diets are diversifying away from basic staples to higher-protection foods, such as meats and dairy products—can also contribute to increases in overall demand for food. These increases in income depend heavily upon changes in total factor productivity and factor endowments. For example, the study of Poncet (2006), takes into account various assumptions of the diffusion of technology among countries, labor force accumulation and estimates of savings rates to produce long-run projections of GDP, labor and productivity growths for a number of countries.

Changes on the supply side—especially those involving agricultural productivity and land use—also need to be considered. Considerable research has been undertaken on productivity growth in agriculture. It appears that agricultural productivity increased relatively rapidly through most of the twentieth century, keeping the prices of key staples generally on a declining trend. While some studies suggest a slowing growth of agricultural productivity, e.g. Alston et al (2009), others, such as Fuglie (2008), conclude that agricultural productivity growth remains strong. In the next section, we consider the various implications of higher agricultural productivity on agricultural output, prices and poverty.

On the supply side, sectorally neutral total factor productivity raises agricultural output more rapidly than demand, because the income elasticity of demand for basic foods is very low. If, however, increases in income are associated with capital deepening, where the capital stock grows more rapidly than output, then another factor comes into play—the Rybczynski (1955) effect. Increases in the stock of capital relative to labor and output can be expected to create pressure for resources to move into more capital-intensive sectors, and out of labor-intensive sectors such as traditional agriculture. A number of studies have found these effects to be substantial, particularly in the case of capital-intensive growth in East Asia (Martin and Warr 1993; Gehlhar, Hertel and Martin 1994).

Agricultural Productivity, Prices and Poverty

The impact of agricultural productivity on poverty has historically been a source of some controversy. Higher productivity can be expected to lower food prices—either at 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 net consumers, and particularly the poorest, who spend around three-quarters of their income on staple foods (Cranfield, Preckel and Hertel 2007). However, many have expressed concern about the potentially adverse impacts of lower commodity prices on the earnings of farmers, and those who earn their incomes as agricultural laborers. As Matsuyama (1992) has pointed out, this is less likely to be a problem when considering a change in agricultural productivity in a single, small, open country than for the world as a whole, or in a closed economy. In the small, open economy case, higher productivity will leave prices unchanged and is likely to stimulate output.

In a closed economy, by contrast, output expansion is likely to be small because of low price elasticities of demand for basic agricultural products. Productivity-induced shifts in the supply curve are likely to cause large declines in prices, and hence to declines in the resources used in the sector. Under these circumstances, employment in a sector benefiting from technical progress is likely to decline. Even stronger concerns for employment have been raised about productivity growth deriving from higher labor productivity in agriculture. Clearly, these concerns apply much more heavily in closed economies than in open ones for a country's own technical change, and are more of an issue for global technical change than for technical change at the country level.

The type of technical change experienced may also be important (Martin and Alston 1997). Technical change that reduces the cost of production on all units produced—a parallel, vertical shift in the supply function—must leave producers as well off following the technical change as before. By contrast, a productivity shift that causes supply curves to shift horizontally, or that increases effective output per unit of input, may leave producers worse off if demand for output is inelastic and the price decline is large enough to outweigh the direct producer benefit from higher productivity. Improvements in productivity may, of course, still lead to reductions in poverty if the benefits of lower prices to poor net consumers outweigh the costs to poor net producers.

Datt and Ravallion (1998) examined the impacts of agricultural productivity growth in India, referring to the controversy that had raged as to whether higher agricultural productivity would be an important source of poverty reduction. They found, using econometric methods, that higher agricultural productivity (proxied through increases in yields) would be expected to reduce poverty substantially in India, partly due to the higher output of small farmers; partly because of lower food costs to net buyers of food, and partly through increases in wage rates for labor sold outside the farm firm. In a subsequent article, de Janvry and Sadoulet (2002) concluded, using stylized computable general equilibrium models, that higher agricultural productivity would lower poverty in the developing countries of Africa, Asia and Latin America, although the channels of effect would differ between regions, with direct income impacts of agricultural productivity growth dominating in Africa; indirect agricultural employment impacts in Asia; and linkage effects with the rest of the economy in Latin America. Minten and Barrett (2008) recently examined this question for Madagascar, taking advantage of more specific information about the rate of productivity growth at the local level. Like Datt and Ravallion (1998), de Janvry and Sadoulet (2002) and Montalvo and Ravallion (2009), they find higher yields lead to poverty reductions.

The implications of higher food prices for poverty are much less likely to be favorable, especially in developing countries. Higher prices for food raise the cost of living of poor consumers (Ivanic and Martin 2008). Further, the benefit that they provide to producers is related not to their output level—as in the case of productivity growth—but to their net sales out of the household. Since many poor farmers in developing countries are net buyers of food, increases in the price of agricultural goods are likely to hurt—rather than help—many poor farmers. The increase in the price of food (or other goods if taxes on other goods are raised to finance subsidies) is also a potential source of loss to poor people. Since few developing countries are likely to be able to raise sufficient taxes from other parts of the economy to pay output subsidies on their agricultural output, and since protection is likely to be partly motivated by a desire to increase food self-sufficiency, we focus on protection provided through import duties on imported goods.

Model

Global Model

Our global simulation is based on the latest (version 7 prerelease 5) GTAP data 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 simulation using the latest GTAP model (Hertel, 1997; www.gtap.org). This model emphasizes the constraints imposed on economies by their overall resource endowments, and takes into account the role of mobility of factors across sectors and overall resource constraints in determining output supplies. Product differentiation between imported and domestic goods and among imports from different regions allow for two-way trade in each product category, depending on the ease of substitution between products from different regions. Factor inputs of land, capital, skilled and unskilled labor, and in some sectors a natural resource factor, are included in the analysis. The model includes the explicit treatment of international trade and transport margins, a "global" bank designed to mediate between world savings and investment, and a relatively sophisticated consumer demand system designed to capture differential price and income responsiveness across countries.

In order to reduce the number of calculations, we use an aggregated version of the model that contains the global geographical regions defined by the World Bank. These regions are presented in Figure 1. With respect to commodities, we aggregated 34 non-agricultural and non-food GTAP commodities into five categories relevant for this work: agricultural farm output, energy, non-durables, durables and services. We preserved all food-related GTAP sectors in the global model, and in some cases we even split those sectors into additional sectors using FAO data on production, prices and trade, and the recently developed MSplitCom software by Mark Horridge. The overview of this split is presented in Table 2.

Because most of our simulations relate either to long-term changes, such as improvements in output productivity, or gradual changes, such as changes in tariffs, we consider a long-run closure that allows complete flexibility of employment of capital and labor and limited flexibility of land use. To maintain consistency with the forward-looking nature of our simulation, we also double the standard GTAP elasticities governing the level of substitution between trade partners to allow for countries to substitute among the sources of their imports. The resulting model includes substantial differentiation of products between domestic and imported goods. 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 goods, which influences the impact of a decline in the price of the domestic good on the average consumer price of that good.

Poverty assessment model

Our model of poverty assessment 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 twenty-one developing countries that span the developing world (Table 1). Our sample includes seven African countries (Côte d'Ivoire, Malawi, Niger, Nigeria, Rwanda, Timor-Leste, Uganda and Zambia), six South and Southeast Asian countries (Bangladesh, Cambodia, Nepal, Pakistan, Timor-Leste and Vietnam), four countries from Latin America (Guatemala, Ecuador, Panama and Peru) and four countries of Europe and Central Asia (Albania, Armenia, Mongolia and Tajikistan). All of the surveys used in this study are relatively recent (see Table 1), and they contain detailed information on the patterns of households' incomes and expenditures.

We used our set of surveys to obtain information on the annual expenditures and incomes of the households as well as the revenues and costs of any family-operated business. The information on household consumption expenditures, including any own-produced consumption, was separated into seven broad categories: agricultural (food) products, non-durables, energy goods, durables, services, financial expenses, and taxes and remittances paid by the household. The category of agricultural products was further divided into 39 individual commodities listed in Table 2. These individual commodities roughly follow the GTAP commodity classification with some additional crops that may be important to the poor, such as sorghum, cassava, coffee and tea, potatoes etc.

Household incomes from agriculture were divided into categories consistent with the expenditure categories, plus 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.).

Behavioral responses of the households in the model were represented using expenditure functions to characterize consumption responses, and profit functions to represent output decisions and input responses. The consumer expenditure functions of the households were calibrated using procedures documented in the Appendix to make the elasticities of demand derived from them consistent with those in the macro model. The profit functions were similarly calibrated to ensure that the elasticities of supply that they imply are consistent with those in the macro model. When prices change, we identify those households whose cost of living less any changes in income moved them across the poverty-line level of utility. We then recalculate poverty gap and poverty headcount for each country following each simulation.

More formally, we assume that a household consumes a set of goods and derives utility which can be represented by an indirect utility function $u(\boldsymbol{p}, y)$ which depends on the household's money income y and the vector of prices $\boldsymbol{p}$. For given prices, the household's income includes labor income $l(\boldsymbol{p})$ and the profit from the household business $\pi(\boldsymbol{p})$, which depends on the output prices while the price of the underlying fixed factors (such as the household's own land and capital) are assumed to exhaust the profits of the business. In other words, we assume that the total amount of labor a household supplies (either to the household's own firm or outside) is fixed as is the amount of land and capital used in the household business.

We define a money measure of the change in households' welfare $\Delta w(\boldsymbol{p})$ resulting from a price change as the difference between the change in profits $\Delta\pi(\boldsymbol{p})$ and labor income $\Delta l(\boldsymbol{p})$, and the change in the cost of achieving the original level of utility $\Delta e(\boldsymbol{p}, u)$, following the change in the vector of prices of factors and consumption goods $\Delta\boldsymbol{p}$. We can write:

$$\Delta w(\boldsymbol{p}) = \Delta\pi(\boldsymbol{p}) + \Delta l(\boldsymbol{p}) + \Delta e(\boldsymbol{p}, u)$$

Using a Taylor series expansion, we obtain a second-order estimate of the change in the cost of utility as $\Delta e = \left(\boldsymbol{p} \cdot \boldsymbol{x}^T \widehat{\boldsymbol{p}} + \frac{1}{2} \cdot [\boldsymbol{p} \cdot \boldsymbol{x} \cdot \widehat{\boldsymbol{p}}]^T \times \epsilon \times \widehat{\boldsymbol{p}}\right)$, where e is the initial level of expenditure, ϵ is a matrix of compensated demand elasticities, $\boldsymbol{p} \cdot \boldsymbol{x}$ is a vector of expenditures on individual items and $\widehat{\boldsymbol{p}}$ is a vector of percentage changes in prices. This specification is convenient for use with household surveys which typically allow the full observation of $p.\boldsymbol{x}$ while $\widehat{\boldsymbol{p}}$ can be supplied from a macroeconomic model. The only parameter that needs to be supplied is the matrix ϵ which can be supplied using the estimated demand parameters and observed consumption shares. In our application, we use the CDE demand parameters estimated for use with the GTAP database to ensure consistency between the macroeconomic and household models. The calculation of the matrix of compensated elasticities is shown in Appendix A.

Because each household's observed consumption is different, the household model contains different compensated demand elasticities for each household, which are also different from those of the representative household in the CGE model, raising a question of consistency of the micro and macro models. However, he aggregate household consumption shares differ only to a small degree from the consumption shares of the representative household, and the parameters of the household demand systems are the same as in the macro-model.

On the supply side, we express the change in profits following a change in prices using a Taylor–Series expansion: $\Delta\pi = \pi \cdot \left([\boldsymbol{p} \cdot \boldsymbol{q}]^T \widehat{\boldsymbol{p}} + \frac{1}{2} \cdot [\boldsymbol{p} \cdot \boldsymbol{q} \cdot \widehat{\boldsymbol{p}}]^T \times \mu \times \widehat{\boldsymbol{p}}\right)$, where μ is a matrix of own and cross-price elasticities, the vector $\boldsymbol{p} \cdot \boldsymbol{q}$ is the observed initial vector of the values of inputs and outputs. It is important to note that $\widehat{\boldsymbol{p}}$ in this evaluation refers to the proportional change in effective prices, i.e. inclusive of the effects of changes in productivity on effective prices. For example, if output productivity is raised by ten percent, we assume that the effective price of output is raised by ten percent, even though consumer prices remain unchanged.

In our model, we estimate and use the elasticity estimates for a three-level combination of two CES functions that determine and the household’s agricultural output, and a Constant Ratio of Elasticities of Transformation, Homothetic (CRETH) function that distributes this output across commodities. At the bottom level, a household firm combines its fixed factors (land, capital) with the mobile factors (labor) in a CES production function. This value-added mix is combined with material inputs using another CES production function that defines total output capacity. The output is finally distributed into individual agricultural products through the CRETH output function. The matrix of elasticities is constrained to match the output supply and input demand elasticities in the model by specifying shares of inputs that are fixed at the household level. The calculation of the matrix of input demand and output supply elasticities is documented in Appendix B. We specified the elasticities of supply in the household model for broad consistency with the elasticities in the macro-model.

Finally, we calculate the change in labor income $\Delta l(p_w)$ as $\Delta l(p_w) = l \cdot p_w \cdot \hat{p}_w$, where $l \cdot p_l$ is the observed labor income. Our treatment assumes that the total amount of labor supplied by the household is fixed while the quantity supplied to the household's own business varies. Increases in wages provide a net gain to the household on labor sold outside the farm firm. The same increase in wages is applied to labor sold to the farm firm but this increase in wages is not a net gain to the farm household as it is directly offset by the increased cost to the farm firm.

Having obtained a change in the income for each household, we then calculate the change in the effective per-capita income. To account for different sizes of households, we use the size elasticity of the cost of living of 0.6 estimated by Lanjouw and Ravallion (1995). This elasticity reflects economies of size in household operation and means that adding an additional member to a household increases the level of income required to maintain per-capita living standards less than proportionately. If, following a simulation, 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 Table 2, were calculated using our household surveys in conjunction with the published poverty rates at a $1.25-a-day poverty line.[1] Using the size elasticity of the cost of living, we identified the effective per-capita expenditure level of the households at the poverty line and used this estimate as the poverty line throughout the study.

Scenarios

Projections

Using projections described in the second section, we formulated a baseline scenario. As is evident in Table 3, these projections imply some noticeable differences between the growth rates of population and of the labor force at the regional level because of changes in dependency ratios. Note also that growth rates of the population and labor force are very low in the industrial countries and in the developing countries of East Asia, and much higher in developing regions such as the Middle East and North Africa; South Asia and Sub-Saharan Africa. High rates of population growth in these regions and high rates of income growth projected for South Asia and MENA contribute to the increase in demand for food over the projection period. We use the annualized 2005–2050 growth projections of Poncet (2006) to project the growth of GDP and the capital stock over the period from 2010 to 2050. With respect to agriculture, we consider two options: a low growth scenario, where agricultural productivity grows at the same rate as other sectors, and one with rates of productivity growth one percentage point per year higher. The higher-

[1] We used the PovCalNet web-based tool to obtain the latest estimates of the poverty rates at $1.25-a-day poverty line definition.

growth scenario involves global-average rates of agricultural TFP growth that are broadly in line with Fuglie's projections of growth rates in agricultural TFP (Fuglie 2008).

While the population projections we use are comprehensive, covering 227 countries and territories, the projections of labor, capital and GDP growth by Poncet (2006) are less so, covering 107 countries or about 83 percent of the world population. Only five countries over 50 million people were missing from the projections: Burma, Ethiopia, Vietnam, Russia and Nigeria. Where necessary, we used estimates for neighboring countries to fill these gaps. The aggregate estimates of GDP growth for the regions used in our model are reported in Table 3.

In our baseline scenario we assume that growth in agricultural productivity is equal to that in the rest of the economy. This assumption in most cases also implies a substantial reduction in the growth rate of agricultural productivity—a notion supported by some recent research. For example, Alston et al (2009) suggest a decline in the global productivity growth for grains from 2.4 percent in the period 1960-1990 to 2.1 percent in the period 1990-2005. Because the observed global agricultural productivity growth of 2.1 percent per year is markedly larger than that in our baseline assumption of 0.6, we think of our sector-neutral-productivity-growth scenario as a lower-bound scenario assuming a certain level of deterioration from past rates of agricultural productivity growth. In our baseline projections, we have not explicitly considered the role of demand for food for biofuels, but this could raise the total demand for food substantially.

Possible policy responses

Our primary policy response scenario involves improvements in agricultural productivity. We first consider changes in agricultural productivity globally, then we consider the impacts of increases in agricultural productivity in developing countries alone and, finally, increases in agricultural productivity in individual regions alone. The last experiment is important because the policy decisions that influence agricultural productivity in developing countries are made by a different set of actors from those influencing productivity growth in the industrial countries. The international institutions and donors involved in the Consultative Group on International Agricultural Research are much more important for developing countries, as are policy makers in national research institutes in developing countries, and the national policy makers involved in decisions about the adoption of new technologies. Once decisions are made to commit resources to improvements in agricultural productivity in developing countries, another important set of decisions that we investigate are those about the allocation of productivity-enhancing resources to different commodities, and extending the improvements in technology to different groups of producers, with the smaller producers frequently being more difficult to reach than the larger, more commercial farmers.

Another potential policy response currently being widely discussed involves increasing national food self-sufficiency levels in an attempt to become more food secure. Such a move towards food self-sufficiency has been stimulated by concerns about the reliability of access to food from world markets during the food price crisis of 2007-8. It remains important to consider its potential impacts on the prices of food to producers and consumers, and hence on poverty and food security at the household level.

Results

Baseline scenario

Our baseline projections are intended not as forecasts but as a plausible backdrop against which to examine policy alternatives. The results for outputs and real prices presented in Tables 4 and 5 appear to be consistent with the consensus that there will need to be substantial growth in agricultural output over the next forty years to meet increasing demand. As reported in Table 4, our projection scenario involves an increase in the global output of basic agricultural products (indexed over production) of about 130 percent. The projected growth rates of output vary considerably by product and by country in response to different demand and supply conditions for each product. While some products, such as poultry meat, have large increases in output in response to high income elasticities, others such as sorghum appear to grow rapidly because of demand patterns in regions with rapid population growth, rather than in response to changes in real incomes.

Under our baseline scenario of uniform productivity growth in agricultural and non-agricultural total factor productivity growth, the prices of many foods rise substantially, with the average value of farm output increasing by over 115 percent. Prices rise more for some—frequently surprising—products consumed in regions with relatively rapid demand growth, such as plantains, whose price increases by over 180 percent. The price of processed food behaves quite differently from that of raw products, with a price increase of only 14 percent overall because of increasing productivity in the processing sector. As a consequence, the overall increase in food prices at the household level is 48 percent.

Possible policies

We undertake counterfactual analyses of different policy alternatives relative to our baseline. The macro impacts of these changes on outputs and real prices are given in the second set of columns of Tables 4 and 5. For a global increase in farm productivity of 1 percent per year, achieved by increasing the effective level of output per unit of input, we find that agricultural output increases by about 180 percent, rather than the 130 percent observed under the baseline. This relatively modest increase in the rate of agricultural productivity growth sharply reduces the increase in prices of farm output, with the average output price rising by only 5 percent, rather than 116 percent. The price of processed foods declines by almost two percent in response to productivity growth in both primary agriculture and food processing, and the overall index of food prices rises by a modest 1.4 percent. These results highlight the fundamental importance of agricultural productivity growth for world food prices.

The third set of columns of Tables 4 and 5 examines the impact of higher productivity in agriculture in developing countries only. This scenario results in larger increases in output in developing countries than the global agricultural productivity scenario but, not surprisingly, smaller global increases in output than the global agricultural productivity scenario. A key consequence, evident in Table 5, is a much larger increase in food prices than under the global agricultural productivity scenario. Global farm output prices rise by 31 percent, much more than the increase under the global productivity scenario. This increase is much smaller than the price increase of 116 percent under the baseline, highlighting the importance of agricultural productivity in developing countries as a group not just for their own performance, but for global market outcomes. The changes in food prices in developing countries are shown in “Dvg” column. These are generally broadly in line with those for the world as a whole, and involve increases averaging 31 percent.

In Table 6 we also report the changes in domestic prices relative to the CPI following the implementation of the protection scenario. In this scenario, we increase import duties on agricultural products in order to reduce imports by fifty percent. Because of the different initial import patterns across regions, different changes in protection are needed to achieve this goal. For those regions that represent the largest importers, such as South Asia and East Asia, significant levels of protection are required, which increase the domestic price of agricultural output by 67 and 138 percent, respectively. Other regions require significantly lower protection and hence smaller increases in domestic prices.

To understand the implications of our global and developing-country policy scenarios at the household level, we use our household models to predict the impacts of these two reforms on poverty in twenty-one countries for which we have detailed information from household surveys. For this analysis, we take into account the changes in prices relative to the baseline, and the direct impacts of productivity on farm incomes. Because we cannot expect to adequately project poverty levels over the projection period, we consider the impacts of price changes, wage changes and productivity changes on incomes in our baseline sample. We report the country-level and the average changes in poverty for the total population as well for rural households. The overall poverty impacts of our scenarios are shown in Table 7. The first column of the table shows the original poverty rate (at 1.25 USD per day per person) as reported in each sample country.

The next column shows the poverty impacts of the policy scenarios as a percentage point change in the poverty headcount from its original rate. An annual one-percent improvement in total factor productivity in agriculture between 2010 and 2050 lowers poverty in all but two of our sample countries, with an average rate of reduction of 5.4 percentage points. The two exceptions—Albania and Nigeria—differ from others for reasons which we explain further below.

In the following column of Table 7, we consider the case where only developing countries benefit from improvements in agricultural productivity. A key feature of this simulation is that the average reduction in poverty is typically in the same order of magnitude as for a global increase in agricultural productivity. This is because most of the benefits of an increase in productivity remain with the country that achieved an increase in its own productivity. Some of these benefits accrue directly to the producers, who benefit from both higher output per unit of input and from a higher effective price of output, which creates incentives for them to expand their output. Further gains accrue from lower prices of food to consumers, and from factor market linkages.

The last column in Table 7 shows the impacts on poverty of a move towards greater self-sufficiency in developing countries. This is implemented by increasing tariffs to a level that halves the current value of imports. This increase turns out to raise poverty in all but one country, Nepal. While many farmers are poor, many of these poor producers are actually net consumers of agricultural products, and hence likely to lose, rather than gain, from higher food prices. The increases in poverty average 2.3 percentage points. These increases in poverty are mitigated to some degree by the responses of households, which expand their output and reduce their consumption of food.

To understand this poverty reduction, we further decompose it into impacts from broad sectors and by whether the impacts come from the consumption or production side in Table 8. The final column of Table 8, for example, shows that the average global reduction in poverty by 5.4 percentage points in the high agricultural productivity growth scenario is mainly caused by the impact of lower agricultural prices on consumption—which result in an average reduction in poverty of 5.5 percentage points. The second most important impact appears to come from rising wages for labor sold off-farm, which lower poverty by an additional 3.0 percentage points. On the other hand, the largest poverty-increasing impact appears to come from the increase in the price of other consumption by 2.9 percentage points—a change linked to the increase in relative prices of those goods that are not affected by improved agricultural productivity.

The impact of price and productivity changes in primary agriculture on producers is generally negative in productivity increasing scenarios: the reason for this is that factor productivity at the local level translates into smaller increases in effective output prices than the global reduction in output prices. As a consequence, farmers who are net sellers of agricultural products often lose out from reductions in the prices of these goods which are not compensated by increases in their effective output prices. This is an illustration of the famous "treadmill" problem in agricultural research, where some producers that do not benefit from an innovation are made worse off by the decline in prices resulting from the innovation. However, it is very important to note that while higher global productivity hurts farms' incomes through lower prices, these prices help all consumers making the net poverty impacts poverty-reducing.

Using the type of decomposition of Table 8, we are now in the position to explain the cases of Albania and Nigeria, the two countries where the poor appear to lose out from the higher productivity gains scenarios. As it turns out, these two countries lose for similar reasons: in both Albania and Nigeria, the poor consume significant amounts of services and nondurables, and energy in Nigeria, whose prices rise relative to the CPI, hurting the poor directly. In addition to that, the agricultural producers in Albania are less factor-intensive, gaining less from improved total factor productivity in agriculture and, as a consequence, they lose disproportionately more from the "treadmill problem."

Our finding that increases in agricultural productivity are, in most cases, an important source of poverty reduction is consistent with those of Montalvo and Ravallion (2009) who showed that increases in agricultural yields were key drivers of poverty reduction in China in the period from 1983 to 2001. Similarly, Minten and Barrett (2008) have found a link from improved agricultural efficiency through lower prices and higher wage incomes to poverty reduction. While our approach lacks the verification associated with econometric approaches, it does allow much greater flexibility in the specification of types of technical change, and provides greater ability to track the impacts through channels such as changes in the prices of services.

Regional differences in agricultural productivity-induced poverty reduction

Besides showing the decomposition of poverty impacts of improved agricultural production globally, Table 8 also shows the same decomposition at the regional level. This decomposition is useful in highlighting the differences in the mechanisms that transform agricultural productivity into poverty reductions in different regions. To illustrate, consider the higher agricultural productivity scenario executed by individual regions (the last set of rows in Table 8). In Sub-Saharan Africa (SSA), the greatest poverty reduction, 3.7 percent, of the total of 5.6 percent is achieved through direct productivity impacts on farmers. In Asia (SAR+EAP), poverty falls on average by 7.3 percent and the dominant reduction of 3.7 percentage points comes from wage impacts. The combined consumer price impacts are small in this region because the benefit of lower agricultural prices (a 3.3 percent reduction in poverty) is largely offset by higher consumer prices in the "other" category (2.0 percent increase in poverty). Finally, in Latin America the benefits of higher agricultural productivity are distributed more equally across the indirect consumer impacts, direct producer impacts, and wage impacts for a total of 2.9 percentage point reduction in poverty.

Role of individual crops in poverty reduction through higher productivity

The poverty results of the three scenarios presented in this section suggest that raising agricultural productivity may have an important role in poverty reduction. Once a decision has been made to commit resources to agricultural R&D, a number of important decisions about the allocation of these resources must be made. Should, for instance, research be focused on staple foods for domestic consumption or for cash crops. Another important question is how much effort should be devoted to extending findings to the smallest—and possibly least easy-to-access producers?

To investigate this further, we calculate poverty impacts for a set of higher agricultural productivity scenarios—similar to the one presented earlier—where we raise global agricultural factor productivity one commodity at a time. As in the previous experiments, we calculate poverty impacts for each scenario following the changes in prices and productivity as observed in the CGE model. The results of this exercise—the average poverty change and a range of one standard deviation from our 21 observations around the mean—are shown in Figure 3. This figure shows that raising total factor productivity of individual commodities may produce very different poverty impacts. For example, while raising the global productivity of some commodities, most notably vegetables, appears to consistently reduce global poverty, raising productivity of other commodities, such as swine, is ambiguous in its impacts. The finding for swine is consistent with the finding by Ivanic and Martin (2008) that increases in the prices of products produced by poor farmers but little consumed by them—such as dairy products—could reduce poverty.

In order to understand the individual commodity results better, in Figure 4 we present a further decomposition of the poverty impacts of some of key commodities with respect to effects on consumers and producers. This figure makes it clear that most of the differences in poverty impacts come from differences in the benefits to consumers, apparently due to the differing importance of individual commodities in consumers' consumption bundles. Net benefits in terms of poverty reduction through gains/losses to producers tend to be smaller and more consistent so the total poverty impact depends primarily on the relative importance of the commodity for consumers. The observed pattern of (small) net losses to pure producers is a consequence of our focus on global productivity, and our particular type of productivity gain, and would not arise for productivity increases in a single small country or region.

The importance of agricultural productivity gains by small farmers

Because the cost of reaching the smallest producers with productivity improvements may be substantially higher than for larger producers, we repeat our earlier scenario of increased global agricultural productivity, with an additional assumption that only some of the farms in developing countries benefit from higher agricultural productivity. More specifically, for each scenario we assume that a certain percentage of the smallest farms, ordered by the size of their farm output, does not benefit at all from their own higher agricultural productivity and is only impacted by changes in the market prices. Because those farmers who do not adopt the new technology reduce the overall productivity gain in developing countries, we scaling down the average agricultural productivity growth for these countries in proportion to the share of the output which is excluded from the technology adoption.

To understand how much of the overall productivity gain is lost by smaller farmers not adopting to improved technology, we first determine the relationship between the farm size and agricultural output from our household survey data and present it in Table 9. This table shows that the bottom twenty percent of farms ordered by the size of their output produce, on average, only 1.6 percent of total agricultural output. These are not the producers who are usually thought of as smallholders—most of these households have such small agricultural output that changes in their productivity have little impact on whether they are above or below the poverty line. Many of them likely derive little of their income from farming. At the other extreme, the top twenty percent of the farms by size produce nearly two thirds of output. The next columns of Table 9 additionally suggest that small farmers tend to be less diversified in their output and significantly poorer than the richest farmers.

The global scenario considered in this analysis is one where the world increases agricultural productivity by one percent over 40 years with a given share of the smallest farms in the developing countries excluded from these gains. We run this simulation for a range of adoption rates from zero to 100 percent at twenty-percentage-point increments. With an adoption rate of 100 percent, the scenario is identical to our earlier presented scenario of higher global agricultural productivity growth; when the adoption rate drops to zero, the scenario becomes one (not discussed in this work) where only developed countries increase their agricultural productivity.

Poverty results for the range of adoption rates are presented in Table 10. In addition to the average poverty change for each adoption rate, we present a decomposition of the poverty results with respect to the differential impacts of agricultural and food prices and productivity on the consumers and producers. We also include a column “other impacts” which contains the rest of the impacts such as changes in wages and prices of other goods which play a little role in this experiment. In line with our earlier findings, the results of these scenarios confirm that improvements in global agricultural productivity are generally favorable to the poor through lower prices, and that they are unfavorable to the producers who face significant drops in the market price only partially compensated by their own effective output price gains.

Table 10 is also illuminating in showing the interplay of two consumer and producer impacts of poverty reduction through higher agricultural productivity. Starting at a 100-percent adoption rate and moving towards 60 percent appears to have little impact on the poverty reduction achieved since the exclusion of the smallest farmers has little impact on consumer prices, and gains in the productivity of such small producers has little effect on their incomes. Only when the adoption rate drops to about 40 percent—and we start to exclude farmers conventionally thought of smallholders—does the poverty-reducing impact of technical change fall because poor farming households lose life-changing income gains. Another critical value for the adoption rate appears to be at about 20 percent, below which the consumers start to lose important benefits from lower food prices.

A similar pattern of the importance of technology adoption among the largest farmers is also apparent for individual commodities. In Figure 5(a), we plot the simulated average poverty reductions for a set of scenarios in which we raise one global agricultural productivity for several key commodities (one at a time) while we also limit technology adoption to various shares of the largest farmers in the developing countries. The figure shows that a major portion of the total benefits to the poor are realized when just the top 20 percent of the farmers adopt a new technology—raising the adoption rate further has a progressively smaller impact on further reductions in poverty. This finding is in line with earlier conclusion that that adoption of higher productivity by the smallest farmers means little for the global poverty reduction even when applied to individual commodities.

Even though improvements of better technology by the smallest farms do not matter much for global poverty change when both direct and indirect impacts are considered, the direct impacts are actually a little more significant that is apparent in Figure 5(a). In Figure 5(b) we show the hypothetical global poverty impacts that would realize if the adoption in technology provided direct income gains to producers but did not result in price changes which benefit consumers but harm producers. This figure suggests that for some commodities, namely wheat, cassava and maize, the adoption of better technology by the smallest farms would lower global poverty more than such adoption by some of the larger farms, but this poverty reduction in poverty is dwarfed by the positive consumer impacts the adoption by the larger farmers creates.

A comparison of total productivity gains with TFP gains for poverty reduction

To this point, we have considered changes in agricultural productivity through improvements in total factor productivity, for which a one-percent increase in productivity is expected to reduce the required amount of factor inputs by one percent in order to produce the identical amount of output. This definition of productivity gains is different from the concept of output productivity which involves the reduction in all inputs involved in producing a given amount of output. Because a TFP gain provides benefits only through reduction in the quantity of factors used, a given rise in TFP always results in a smaller overall gain to the producer than an equal rise in gross output productivity. This difference between the two outcomes is bigger for commodities that are less factor-intensive, and more intensive in their use of intermediate inputs.

In Figures 6(a) and 6(b) we present the average global poverty changes for five commodities for various rates of technology adoption. In Figure 6(b) we show the direct impacts, through changes in producer returns at constant prices, of higher output productivity. Unlike in our earlier experiment presented in Figure 5(b), the commodity with the greatest poverty-reducing impact now appears to be rice. The rank reversal from our earlier simulations is due to the fact that rice is more input intensive and hence less factor-intensive than vegetables, so its producers benefit less from a TFP improvement than producers of the more factor-intensive vegetable production.

Another interesting observation from Figure 6(a) is that the rank of individual commodities for poverty reduction from improvements in technology may change as adoption rates decline. For example, even though a one-percent change in output productivity of rice appears to be benefiting producers more than the same productivity change in vegetables as seen in Figure 6(b), when the indirect impacts are added in Figure 6(a), the rank for poverty reduction reverses at the 40 percent adoption rate. This means that the choice of the commodity for poverty reduction through higher agricultural productivity depends on whether this technology change can reach the smallest farmers or not, as is the case with vegetables and rice, or wheat and maize.

Conclusions

In this study we investigated various drivers of poverty change in the coming decades. More specifically, we considered various types of growth, such as growth in population, labor, capital and productivity, and modeled the impacts of these patterns of growth on poverty. Our baseline simulation—involving uniform rates of technical progress across all sectors— involves substantial increases in prices of agricultural commodity prices. When, however, we allow for agricultural productivity growth rates one percent above those for the rest of the economy, these price increases are essentially neutralized.

Consistent with the findings in the econometric literature, we find that raising global agricultural productivity reduces poverty in developing countries. However, our analysis also shows that nearly all of the positive impacts come from the favorable reductions in the cost of food consumption; the direct impact of improved agricultural productivity is often negative for farmers whose gains from higher productivity with the (standard) specification that we use are smaller than their losses from lower output prices.

If developing countries respond to the current climate of concern about food security by raising protection on agricultural commodities, the implications for poverty are likely to be unfavorable—even though farmers benefit from increased food prices on their output, net consumers—many of whom are also farmers—suffer even more in terms of poverty measures.

The findings of our work have confirmed the existence of regional differences in the linkages between poverty and agricultural productivity. Similarly to the conclusions of de Janvry and Sadoulet (2002), we find that in Asia most of the poverty reducing benefits of higher agricultural productivity come from real wage increases. On the other hand we show that in Latin America benefits of agricultural productivity on poverty come mainly from the reduced food prices as well as the reduced prices of processed food, along with relatively small benefits in the form of higher wages.

In our work we also addressed the issue of identifying specific crops with the greatest poverty-reducing potential through improved productivity, and the issue of the importance of adoption of this improved technology by the smallest farmers in order to realize the gains in poverty reduction. We find that rice, vegetables and maize have the greatest direct impact on poverty through higher productivity and higher effective output prices. Our analysis shows that the overall impact on poverty changes is often not very sensitive to the adoption rate of the new technology by the smallest farms: this is especially true for those commodities whose main poverty-reduction benefit is derived through favorable price impacts, such as wheat. In several other commodities, for example rice, the adoption of the improved productivity by the smallest farmers appears to be relatively important.

Much more work needs to be done to address many of the questions raised in this paper. The results presented refer only to very broad scenarios of productivity growth across regions and commodities. Many decisions about resource allocation must be taken for individual countries—or even regions within countries—and the results of decisions in these contexts may be quite different. In particular, improvements in productivity at the individual region level are much less likely to have many of the offsetting effects on commodity prices that are experienced at the global level. A much wider country coverage is also required to obtain results that are representative for the developing world as a whole. The analysis in this paper is intended as only a first step towards addressing these important issues.

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Appendix A: Deriving the matrix of compensated demand elasticities with CDE preferences

For comparability with the macro model, we use the Constant Difference of Elasticities (CDE) specification to characterize consumer demand. Following Hanoch (1975), we define a matrix of compensated elasticities ϵ for CDE preferences as :

$\epsilon_{i,j} = \left(\alpha_i + \alpha_j - \boldsymbol{\sigma}^T \times \boldsymbol{\alpha}\right)\sigma_j$, when $i \neq j$, and $\epsilon_{i,j} = \left(\alpha_i + \alpha_j - \boldsymbol{\sigma}^T \times \boldsymbol{\alpha}\right)\sigma_j - \alpha_i \frac{\sigma_j}{\sigma_i}$, when $i = j$, where $\boldsymbol{\alpha}$ is the vector of CDE substitution parameters and $\boldsymbol{\sigma}$ is the vector of consumption shares.

For consistency with the macro model, we used the previously estimated values of $\boldsymbol{\alpha}$ from the parameter file accompanying the GTAP database, shown in Table A1. When only regional estimates were available, we assigned those values to all countries included in the region so that, for example, the parameter values estimated for Western Africa were applied to Côte d'Ivoire since no country specific estimate was available for that country.

The values of $\boldsymbol{\sigma}$ were obtained directly from the household survey data by calculating the observed consumption shares for each commodity relative to total consumption. This vector of consumption shares was therefore calculated for each household, meaning that each household was assigned slightly different elasticities of substitution using the formula presented above. It is important to note that the observed differences in the matrices of compensated price elasticities were assumed to be solely the result of the differences in prices that each household faced in its consumption decision and not differences in household incomes.

Appendix B: Calculation of the input/output price elasticities for a CES–CES–CRETH composite production function

The production system used in this work is designed to obtain consistency with the response elasticities in the macro model; while maintaining the theoretical restrictions on household behavior; and tracking the impacts of price and productivity changes on household welfare. It allows for the fact that farm households have production activities that frequently involve a significant number of commodities; that use material inputs; and that demand both family and hired labor.

The specification used involves a combination of CRETH and CES functions. At the bottom level, a household firm combines its fixed inputs (land, capital) with the mobile inputs (labor) in a CES production function. This value-added mix is then combined with inputs in another CES production function into a total output capacity. The output is finally distributed into individual agricultural products through the CET output function.

The top-level CRETH function can be described by the following system of equations $\forall k$: $\hat{q}_k$-$\hat{q}_o = \sigma_{T_i}(\hat{p}_k - \hat{p}_o)$, where q_k is the output of product k with price p_k, q_o is the output capacity with price p_o. σ_T is the positive elasticity of substitution. The zero profits condition for this nest means that the value of all outputs equals the value of output capacity:

$\sum_k s_k^* \hat{p}_k$where s_k^* is the elasticity-weighted share of output devoted to good k: $s_k^* = \frac{\sigma_{T_i} s_k}{\sum_l \sigma_{T_i} s_l}$.

A CES function links the output capacity to the level of value-added composite q_v with price p_v and inputs q_i with price p_i and the negative elasticity of substitution σ_V:

$\hat{q}_o - \hat{q}_v = \sigma_V(\hat{p}_o - \hat{p}_v)$ and $\hat{q}_o - \hat{q}_i = \sigma_V(\hat{p}_o - \hat{p}_i)$.

The zero-profit condition again requires that $\hat{p}_o = s_i\hat{p}_i + s_v\hat{p}_v$, where s_i is the share of inputs in output and s_v is the share of value-added.

The value-added composite is produced using fixed q_f and mobile factors q_m in another CES sub-nest with the negative elasticity of substitution σ_F.

$$\hat{q}_v - \hat{q}_f = \sigma_F(\hat{p}_v - \hat{p}_f)$$

$$\hat{q}_v - \hat{q}_m = \sigma_F(\hat{p}_v - \hat{p}_m)$$

With the zero-profit condition represented by $\hat{p}_v = s_f\hat{p}_f + s_m\hat{p}_m$, where $s_f$is the share of the fixed factor in the value-added and s_m is the share of the mobile factor.

In our application, we assume that a household firm is a price taker in its output, input and variable factor market. The fixed input is assumed to belong to the household and its shadow price is adjusted to assure zero profits of the firm while its quantity is fixed ($\hat{q}_f = 0$).

Our goal is to fill in the matrix μ of cross-price elasticities of the production quantities which we seek to express as a linear combination of elasticities of substitution contained in the production structure. For the sake of the illustration of cross-price output elasticities, we include two output goods (k and l) in our calculations.

$$\mu = \begin{bmatrix} \frac{\hat{q}_k}{\hat{p}_k} & \frac{\hat{q}_k}{\hat{p}_l} & \frac{\hat{q}_k}{\hat{p}_m} & \frac{\hat{q}_k}{\hat{p}_i} \\ \frac{\hat{q}_l}{\hat{p}_k} & \frac{\hat{q}_l}{\hat{p}_l} & \frac{\hat{q}_l}{\hat{p}_m} & \frac{\hat{q}_l}{\hat{p}_i} \\ \frac{\hat{q}_m}{\hat{p}_k} & \frac{\hat{q}_m}{\hat{p}_l} & \frac{\hat{q}_m}{\hat{p}_m} & \frac{\hat{q}_m}{\hat{p}_i} \\ \frac{\hat{q}_i}{\hat{p}_k} & \frac{\hat{q}_i}{\hat{p}_l} & \frac{\hat{q}_i}{\hat{p}_m} & \frac{\hat{q}_i}{\hat{p}_i} \end{bmatrix}$$

$$\mu = \begin{bmatrix} \sigma_k(1-s_k^*) & -\sigma_k s_l^* & 0 & 0 \\ -\sigma_l s_k^* & \sigma_l(1-s_k^*) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} + \sigma_V \begin{bmatrix} -\frac{s_k^* s_i}{s_v} & -\frac{s_l^* s_i}{s_v} & 0 & \frac{s_i}{s_v} \\ -\frac{s_k^* s_i}{s_v} & -\frac{s_l^* s_i}{s_v} & 0 & \frac{s_i}{s_v} \\ 0 & 0 & 0 & 0 \\ -\frac{s_k^*}{s_v} & -\frac{s_l^*}{s_v} & 0 & \frac{1}{s_v} \end{bmatrix}$$

$$+ \sigma_F \begin{bmatrix} -\frac{s_k^* s_m}{s_f s_v} & -\frac{s_l^* s_m}{s_f s_v} & \frac{s_m}{s_f} & \frac{s_i s_m}{s_f s_v} \\ -\frac{s_k^* s_m}{s_f s_v} & -\frac{s_l^* s_m}{s_f s_v} & \frac{s_m}{s_f} & \frac{s_i s_m}{s_f s_v} \\ -\frac{s_k^*}{s_f s_v} & -\frac{s_l^*}{s_f s_v} & \frac{1}{s_f} & \frac{s_i}{s_f s_v} \\ -\frac{s_k^* s_m}{s_f s_v} & -\frac{s_k^* s_m}{s_f s_v} & \frac{s_m}{s_f} & \frac{s_i s_m}{s_f s_v} \end{bmatrix}$$

The values of the production elasticity matrix were calculated using the formula above. The values of σ_F and σ_V were obtained from the GTAP parameter file and they are reported in Table B1.The values of top-level output substitution parameters $\sigma$for agricultural commodities were estimated from the global GTAP model, in which we randomly perturbed output taxes for all commodities, allowing us to measure the level of substitution of outputs with respect to the changes in relative prices of other outputs. The resulting substitution elasticities are reported in Table B2.

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Table 1: Household surveys included in this study

Country	Survey name	Year	Number of households	Number of people	Rural households	Poverty rate	Rural poverty rate
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
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
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	5071	28,099	3,655	55.1	67.0
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
Tajikistan	Living Standards Measurement Survey	2007	4644	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
Zambia	Living Conditions Monitoring Survey	2002	4,166	23,074	2,090	61.9	59.4

Table 2: Commodities included in analysis (original GTAP sector specified for introduced sectors in agriculture)

Agriculture			Non-agriculture
Wheat	Vegetables (V_F)	Plant-based fibers	Nondurables
Rice	Coffee and tea (OCR)	Wool	Durables
Maize (GRO)	Other crops (OCR)	Processed cattle meat (CMT)	Services
Sorghum (GRO)	Forestry	Other processed bovine meat (CMT)	Energy
Other grains (GRO)	Fishing	Other processed food	Remittances
Other oil seeds (OSD)	Cattle meat (CTL)	Other processed meat (OMT)	Transfers/taxes
Peanuts (OSD)	Other bovine meat (CTL)	Processed poultry meat (OMT)	
Soybeans (OSD)	Poultry meat (OAP)	Processed swine meat (OMT)	
Sugar cane and beets	Swine meat (OAP)	Processed sugar	
Cassava (V_F)	Dairy	Oils and fats	
Fruits (V_F)	Eggs (OAP)	Processed tobacco and beverages	
Plantains (V_F)	Other animal products (OAP)		
Potatoes (V_F)	Raw milk		

Table 3: Projected growth rates and total growth between 2010 and 2050 in the baseline scenarios (in pct)

	Population[2]		Capital[3]		Labor[4]		GDP[5]		Implied TFP productivity growth	
	2010-50	Annual	2010-50	Annual	2010-50	Annual	2010-50	Annual	2010-50	Annual
Developed	10.4	0.2	153.8	2.4	8.7	0.2	148.8	2.3	66.4	1.3
East Asia	10.2	0.2	793.2	5.6	11.2	0.3	533.1	4.7	113.0	1.9
Europe & C. Asia	-3.7	-0.1	130.9	2.1	11.8	0.3	106.8	1.8	33.8	0.7
Latin America	32.8	0.7	107.8	1.8	33.2	0.7	87.9	1.6	16.5	0.4
MENA	51.7	1.0	218.8	2.9	52.7	1.1	199.3	2.8	29.3	0.6
South Asia	44.2	0.9	471.3	4.5	42.4	0.9	471.5	4.5	135.0	2.2
Sub-Sah. Africa	119.6	2.0	119.9	2.0	90.6	1.6	98.7	1.7	8.3	0.2
TOTAL	33.8	0.7	199.8	2.8	29.3	0.6	174.6	2.6	—	—

[2] Source: US Census Bureau
[3] Source: Poncet (2006)
[4] Source: Poncet (2006)
[5] Source: Poncet (2006)

Table 4: Overview of global price changes (in pct)

	Baseline		Ag TFP+1		Ag TFP+1 in developing	
	World	Dvg	World	Dvg	World	Dvg
Farm output	126.9	121.7	179.1	183.1	166.0	205.1
Fishing and forestry	249.1	276.6	274.8	303.2	270.7	298.7
Processed food	124.6	94.7	154.6	164.0	145.7	157.2
All food	126.0	112.9	164.7	178.9	154.6	185.8
Rice	139.7	147.5	183.5	188.5	173.7	218.5
Wheat	134.2	112.5	173.7	136.7	175.4	201.7
Other grains	105.3	87.8	147.0	137.6	139.3	152.3
Maize	110.4	91.7	148.7	139.4	139.5	155.1
Sorghum	151.4	159.4	203.0	221.8	194.3	219.1
Cassava	101.6	101.1	142.2	143.5	136.8	145.6
Plantains	160.8	161.2	220.3	220.3	212.6	218.3
Potatoes	94.7	89.0	128.7	137.6	123.6	155.6
Vegetables	106.5	106.8	142.6	158.9	135.3	185.7
Fruits	108.9	108.1	146.4	158.1	138.7	187.2
Other oilseeds	118.3	104.5	187.7	152.8	166.6	178.4
Peanuts	112.1	84.6	177.1	124.9	153.7	187.6
Soybeans	137.7	134.7	220.8	208.6	195.5	226.9
Sugar cane and beets	123.3	96.6	185.9	193.8	175.8	184.9
Plant-based fibers	203.1	211.9	295.1	240.4	262.8	327.1
Other crops	104.5	64.1	128.2	78.6	124.2	156.8
Coffee and tea	112.1	89.0	136.4	125.9	130.4	184.1
Tobacco	123.3	100.3	147.3	149.2	139.7	159.8
Other bovine meat	78.4	52.0	176.5	149.0	151.3	149.2
Cattle meat	84.3	116.5	163.0	190.7	141.3	203.2
Other animal products	156.7	118.8	236.0	184.1	217.5	202.8
Eggs	163.5	162.1	245.4	271.9	222.1	260.3
Poultry meat	165.9	147.9	237.5	259.6	215.9	265.6
Swine meat	116.0	71.4	169.9	189.6	147.9	189.7
Raw milk	127.6	100.2	173.6	191.2	159.2	193.3
Wool	283.9	288.4	329.2	244.5	352.4	382.7
Forestry	284.0	304.8	304.8	311.3	300.4	306.6
Fishing	213.8	249.8	244.5	294.7	240.6	290.3
Other proc. bov. meat	98.3	67.3	150.5	168.2	143.9	134.1
Processed cattle meat	50.4	180.5	135.7	133.2	115.0	150.0
Other processed meat	118.3	251.9	139.6	257.5	132.9	245.5
Processed poultry meat	143.5	11.8	189.1	200.4	175.3	200.5
Processed swine meat	89.5	430.8	128.6	126.9	116.7	229.7
Oils and fats	132.8	177.8	170.5	176.3	161.5	183.7
Dairy	119.4	58.9	145.4	147.2	137.5	136.7
Sugar	137.0	40.8	163.8	161.8	155.4	150.8
Other processed food	128.0	46.9	152.9	147.5	144.5	130.9
Proc. tobacco & bev.	149.0	174.9	166.8	211.9	161.6	206.7
Energy	206.7	272.5	212.4	255.4	210.2	255.6
Non-durables	204.7	297.4	209.7	359.9	207.8	338.2
Durables	203.5	674.5	205.5	598.3	204.9	601.3
Services	177.1	303.0	179.6	322.7	178.7	319.2

Table 5: Overview of global price changes (in pct, deflated by global CPI)

	Baseline		Higher agric growth		Higher ag growth dvlpng	
	World	Dvg	World	Dvg	World	Dvg
Farm output	115.6	111.9	4.8	12.8	31.0	31.4
Fishing and forestry	8.2	5.4	17.0	26.4	15.2	22.2
Processed food	14.0	13.5	-1.8	-0.6	3.3	3.6
All food	48.3	63.3	1.4	8.0	13.5	19.2
Rice	67.5	55.2	1.3	5.7	16.0	13.4
Wheat	109.8	93.5	0.5	2.8	26.3	22.7
Other grains	122.3	110.0	1.0	5.2	29.1	25.3
Maize	128.6	120.7	1.1	6.3	30.9	28.4
Sorghum	157.3	150.1	15.5	22.2	41.0	40.6
Cassava	126.0	106.3	1.7	1.5	21.7	18.1
Plantains	181.0	155.9	25.8	25.2	47.1	43.4
Potatoes	124.6	115.8	3.2	10.2	30.2	29.6
Vegetables	130.9	129.5	6.3	17.8	35.0	38.4
Fruits	133.4	130.4	6.3	16.5	34.9	37.5
Other oilseeds	130.5	111.8	4.7	6.2	31.8	28.3
Peanuts	109.3	94.8	-3.2	1.8	31.0	27.7
Soybeans	149.6	144.9	10.9	18.4	39.2	39.1
Sugar cane and beets	135.6	119.6	10.3	15.7	35.4	33.2
Plant-based fibers	123.1	106.5	6.6	11.0	34.8	32.0
Other crops	113.7	102.1	-5.8	-2.3	29.1	27.4
Coffee and tea	117.2	113.8	-4.3	2.3	29.8	30.1
Tobacco	122.3	123.8	-3.3	5.7	31.0	26.9
Other bovine meat	105.0	92.4	4.9	7.5	29.7	26.9
Cattle meat	77.9	94.0	-4.3	5.6	24.2	23.2
Other animal products	127.4	109.6	11.4	12.9	35.2	31.9
Eggs	129.2	136.5	16.5	26.6	40.0	45.3
Poultry meat	117.0	138.1	12.3	28.3	37.5	48.1
Swine meat	76.4	110.5	-1.5	14.4	24.5	36.2
Raw milk	101.2	110.4	-0.1	8.9	27.5	29.0
Wool	148.3	123.7	11.3	10.6	39.5	34.8
Forestry	2.0	-1.0	10.0	18.6	8.3	14.6
Fishing	15.5	12.3	25.3	34.5	23.3	30.2
Other proc. bov. meat	6.6	-1.0	-0.3	-2.1	4.0	2.1
Processed cattle meat	23.6	8.0	-2.6	-4.3	8.3	1.8
Other processed meat	-3.8	-13.8	-2.2	-5.2	-1.4	-5.3
Processed poultry meat	30.0	35.2	4.2	10.6	12.7	17.5
Processed swine meat	22.2	9.6	-1.8	-3.8	7.2	1.7
Oils and fats	25.0	12.3	-1.0	-1.5	6.9	3.9
Dairy	13.8	11.6	-2.5	-2.5	2.9	1.6
Sugar	27.2	28.1	0.4	1.0	6.8	6.1
Other processed food	13.7	21.5	-1.0	1.8	3.5	6.6
Proc. tobacco & bev.	3.6	-1.1	-5.1	-5.5	-2.6	-4.3
Energy	-6.0	-15.5	0.8	0.3	-0.9	-3.2
Non-durables	-4.7	-13.1	-0.6	-2.6	-1.7	-4.8
Durables	-6.4	-18.8	-0.2	-4.8	-1.7	-7.9
Services	-5.9	-17.5	-0.4	-3.5	-1.9	-6.5

Table 6: Regional price impacts of the protection scenario (relative to baseline; percent changes)

	EAP	ECA	LAC	SAR	SSA
Farm output	138.2	3.2	2.0	67.4	3.2
Fishing and forestry	-25.9	-0.8	-0.3	-23.0	-2.8
Processed food	21.5	1.4	1.1	-1.9	0.5
All food	102.6	3.2	1.7	49.7	4.1
Rice	43.7	0.5	1.9	-11.6	17.9
Wheat	146.2	0.7	12.1	70.2	53.8
Other grains	158.5	1.2	7.0	73.7	2.5
Maize	161.5	3.3	4.0	57.8	5.7
Sorghum	119.5	0.0	-0.7	46.0	0.4
Cassava	122.6	1.3	1.1	92.5	-0.2
Plantains	126.2	9.6	0.7	69.5	7.8
Potatoes	143.2	3.3	4.2	115.0	1.7
Vegetables	142.2	4.3	2.0	114.9	5.0
Fruits	142.2	4.0	2.2	111.9	4.6
Other oilseeds	342.3	9.9	1.2	84.2	-2.3
Peanuts	396.2	32.9	0.9	91.2	-2.4
Soybeans	436.6	23.5	0.9	71.6	17.6
Sugar cane and beets	119.4	-2.0	-0.8	3.5	-3.7
Plant-based fibers	197.5	1.1	3.6	74.6	-0.8
Other crops	458.4	16.5	1.9	172.9	-2.8
Coffee and tea	191.9	19.0	0.7	125.4	25.0
Tobacco	345.5	1.1	0.3	105.9	-1.5
Other bovine meat	265.9	1.7	0.2	27.6	-1.0
Cattle meat	315.3	1.7	0.4	57.7	0.3
Other animal products	140.4	5.8	1.4	60.1	-1.8
Eggs	122.9	4.1	1.3	116.4	-0.2
Poultry meat	134.4	8.3	2.4	146.0	-0.3
Swine meat	184.5	10.3	2.8	162.7	18.1
Raw milk	231.1	3.0	4.0	85.9	2.7
Wool	190.4	0.1	1.5	123.4	-4.3
Forestry	-26.6	-0.7	-0.1	-20.6	-2.3
Fishing	-24.9	-1.0	-0.4	-25.4	-3.7
Other proc. bov. meat	122.4	0.2	0.6	-16.3	-0.3
Processed cattle meat	121.3	0.7	0.7	-10.0	-0.3
Other processed meat	-2.1	-0.6	0.0	-8.2	-1.8
Processed poultry meat	81.6	1.3	0.7	15.1	-0.5
Processed swine meat	5.0	1.6	1.1	2.0	-2.1
Oils and fats	52.0	2.2	1.4	37.8	-0.6
Dairy	48.5	0.5	1.4	-1.3	-0.5
Sugar	36.8	2.7	0.4	-7.4	-1.5
Other processed food	42.8	1.5	1.5	7.6	1.8
Proc. tobacco & bev.	14.7	1.4	0.6	-4.1	-0.4
Energy	-18.9	-0.7	-0.2	-19.6	-2.4
Non-durables	-8.6	-0.7	-0.2	-10.9	-2.2
Durables	-15.8	-0.8	-0.2	-17.7	-2.2
Services	-13.8	-0.8	-0.3	-19.0	-2.3

Table 7: Country level poverty impacts (relative to the baseline)

	Original rate	Change (pct points)		
	(pct points)	Ag prod +1, Global	Ag Prod +1, dvlpng	Protection dvlpng
Albania	0.8	1.0	0.4	0.0
Armenia	10.6	-2.0	-1.8	0.3
Bangladesh	50.5	-16.0	-14.5	9.2
Cote d'Ivoire	23.3	-3.8	-4.7	0.7
Ecuador	15.8	-4.5	-4.3	0.3
Guatemala	12.6	-7.0	-6.4	0.7
Cambodia	40.2	-3.0	-3.8	2.7
Mongolia	22.4	-3.9	-3.6	-0.1
Malawi	73.9	-12.1	-11.7	0.7
Nepal	55.1	-4.4	-4.4	-0.9
Nigeria	64.4	2.6	0.8	0.0
Niger	65.9	-2.3	-2.6	0.8
Pakistan	22.6	-13.8	-12.3	22.4
Panama	9.4	-2.4	-2.3	0.1
Peru	7.9	-2.0	-2.0	0.2
Rwanda	76.6	-2.4	-2.1	0.2
Tajikistan	21.5	-7.6	-7.0	0.8
Timor-Leste	52.9	-10.8	-9.7	5.8
Uganda	51.5	-7.0	-7.1	0.1
Vietnam	21.4	-4.8	-6.2	3.7
Zambia	61.9	-6.7	-6.6	1.6
Average	36.2	-5.4	-5.3	2.3

Table 8: Decomposition of the sources of poverty change (percentage point changes in average poverty rate)

		Raw ag		Processed food		Fishing and forestry		Other		Wage	Total
		Consumption	Production	Consumption	Production	Consumption	Production	Consumption	Production		
Higher ag productivity	World	-5.5	1.5	-0.5	0.2	0.3	-0.3	2.9	-1.1	-3.0	-5.4
	SSA	-7.1	1.3	0.1	0.0	0.6	-0.1	4.3	-1.4	-2.2	-4.5
	LAC	-3.8	1.4	-1.0	0.2	0.0	0.0	0.3	-0.2	-1.0	-4.0
	SAR+EAP	-6.2	2.0	-0.4	0.1	0.5	-0.7	4.2	-2.1	-6.1	-8.8
	ECA	-3.8	1.4	-1.5	0.7	0.0	0.0	1.1	0.0	-1.4	-3.5
Higher ag productivity developing	World	-4.4	0.5	-0.3	0.1	0.3	-0.2	2.2	-0.9	-2.5	-5.3
	SSA	-5.8	0.1	0.1	0.0	0.4	-0.1	3.2	-1.0	-1.8	-4.8
	LAC	-3.1	0.7	-0.7	0.2	0.0	0.0	0.2	-0.2	-0.9	-3.8
	SAR+EAP	-5.1	0.7	-0.2	0.1	0.4	-0.6	3.3	-1.8	-5.2	-8.5
	ECA	-3.2	0.9	-1.0	0.5	0.0	0.0	0.7	-0.1	-1.2	-3.4
Protection by developing countries	World	2.4	-2.1	-0.3	-0.1	-0.2	0.3	-1.3	1.1	2.5	2.3
	SSA	1.2	-0.4	-0.1	0.0	-0.1	0.0	-0.6	0.2	0.3	0.6
	LAC	0.3	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3
	SAR+EAP	6.6	-6.7	-0.9	-0.3	-0.5	1.0	-3.7	3.6	8.1	7.1
	ECA	0.3	-0.2	0.1	0.0	0.0	0.0	-0.1	0.0	0.2	0.2
Higher ag productivity in own region	World	-2.0	-1.8	-0.1	0.0	0.1	-0.1	1.0	-0.5	-1.6	-4.9
	SSA	-1.9	-3.7	0.1	0.0	0.2	-0.1	0.9	-0.4	-0.9	-5.6
	LAC	-1.2	-0.9	-0.3	0.1	0.0	0.0	0.1	-0.1	-0.5	-2.9
	SAR+EAP	-3.3	-1.1	0.0	0.0	0.2	-0.4	2.0	-1.0	-3.7	-7.3
	ECA	-0.9	-0.5	-0.3	0.2	0.0	0.0	0.2	0.0	-0.7	-2.0

Table 9(a): Key statistics by farm size

Farm size rank	Average share of agricultural output	Average number of commodities produced[6]	Average poverty rate	Average population share
Non-farmers	0	0	26.7	23.0
0–20%	1.6	2.3	44.5	13.0
20–40%	4.8	2.3	48.1	13.8
40–60%	9.5	2.7	45.7	14.9
60–80%	18.0	3.0	39.9	16.4
80–100%	66.2	3.0	22.1	18.8
Total	100.0	—	36.2	100.0

[6] Calculated as the inverse of the Herfindahl index

Table 10: Decomposition of the poverty impacts of improved agricultural productivity (percentage point changes in average poverty)

Adoption rate	Consumers	Producers—productivity	Producer—prices	Rest	Total
100%	-5.6	-3.0	4.4	-0.8	-5.0
80%	-5.6	-2.9	4.3	-0.8	-5.0
60%	-5.5	-2.7	4.2	-0.8	-4.8
40%	-5.3	-2.2	3.9	-0.8	-4.4
20%	-5.0	-1.2	3.3	-0.8	-3.6
0%	-3.1	0.0	2.3	-0.5	-1.3

Table A1: CDE demand substitution parameters used in this work

	ALB	ARM	BGD	CIV	ECU	KHM	GTM	MNG	MWI	NEP	NGA	NIG	PAK	PAN	PER	RWA	TJK	TLS	UGA	VNM	ZMB
Beverages and tobacco	0.77	0.79	0.89	0.88	0.78	0.91	0.79	0.82	0.93	0.88	0.89	0.78	0.87	0.74	0.78	0.88	0.74	0.81	0.91	0.88	0.88
Sugar cane	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.87	0.86	0.94	0.90	0.90
Processed cattle meat	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.77	0.83	0.76	0.79	0.84	0.76	0.76	0.84	0.83	0.83
Other processed bovine meat	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.77	0.83	0.76	0.79	0.84	0.76	0.76	0.84	0.83	0.83
Cattle	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.80	0.83	0.76	0.79	0.84	0.77	0.78	0.84	0.83	0.83
Other bovines	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.80	0.83	0.76	0.79	0.84	0.77	0.78	0.84	0.83	0.83
Forestry	0.67	0.71	0.84	0.84	0.69	0.85	0.70	0.76	0.89	0.81	0.82	0.76	0.81	0.65	0.69	0.83	0.66	0.75	0.86	0.83	0.83
Fish	0.79	0.77	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.82	0.83	0.77	0.79	0.84	0.72	0.77	0.84	0.83	0.83
Maize	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.87	0.87	0.94	0.90	0.90
Other grains	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.87	0.87	0.94	0.90	0.90
Sorghum	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.87	0.87	0.94	0.90	0.90
Processed milk	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.76	0.83	0.76	0.79	0.84	0.76	0.78	0.84	0.83	0.83
Eggs	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.79	0.83	0.76	0.79	0.84	0.76	0.74	0.84	0.83	0.83
Other animal products	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.79	0.83	0.76	0.79	0.84	0.76	0.74	0.84	0.83	0.83
Poultry	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.79	0.83	0.76	0.79	0.84	0.76	0.74	0.84	0.83	0.83
Swine	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.79	0.83	0.76	0.79	0.84	0.76	0.74	0.84	0.83	0.83
Coffee and tea	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.90	0.89	0.88	0.88	0.90	0.87	0.87	0.94	0.90	0.90
Other crops	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.90	0.89	0.88	0.88	0.90	0.87	0.87	0.94	0.90	0.90
Tobacco	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.90	0.89	0.88	0.88	0.90	0.87	0.87	0.94	0.90	0.90
Other food	0.77	0.78	0.89	0.88	0.78	0.91	0.79	0.82	0.93	0.88	0.89	0.80	0.87	0.74	0.78	0.88	0.74	0.83	0.91	0.88	0.88
Other processed meat	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.78	0.83	0.77	0.79	0.84	0.76	0.79	0.84	0.83	0.83
Poultry meat	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.78	0.83	0.77	0.79	0.84	0.76	0.79	0.84	0.83	0.83
Pork	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.78	0.83	0.77	0.79	0.84	0.76	0.79	0.84	0.83	0.83
Other oil seeds	0.91	0.89	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.90	0.87	0.94	0.90	0.90
Peanuts	0.91	0.89	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.90	0.87	0.94	0.90	0.90
Soybeans	0.91	0.89	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.90	0.87	0.94	0.90	0.90
Plant-based fibers	0.75	0.77	0.84	0.84	0.76	0.82	0.77	0.78	0.86	0.82	0.79	0.73	0.83	0.73	0.76	0.83	0.74	0.52	0.84	0.83	0.83
Rice	0.91	0.87	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.90	0.89	0.89	0.88	0.90	0.87	0.88	0.94	0.90	0.90
Raw milk	0.79	0.79	0.84	0.84	0.79	0.83	0.80	0.79	0.86	0.82	0.79	0.78	0.83	0.77	0.79	0.84	0.76	0.86	0.84	0.83	0.83
Sugar	0.77	0.79	0.89	0.88	0.78	0.91	0.79	0.82	0.93	0.88	0.89	0.79	0.87	0.75	0.78	0.88	0.75	0.82	0.91	0.88	0.88
Cassava	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.88	0.87	0.94	0.90	0.90
Fruits	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.88	0.87	0.94	0.90	0.90
Plantains	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.88	0.87	0.94	0.90	0.90
Potatoes	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.88	0.87	0.94	0.90	0.90
Vegetables	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.91	0.89	0.89	0.88	0.90	0.88	0.87	0.94	0.90	0.90
Oils	0.77	0.79	0.89	0.88	0.78	0.91	0.79	0.82	0.93	0.88	0.89	0.82	0.87	0.75	0.78	0.88	0.75	0.82	0.91	0.88	0.88
Wheat	0.91	0.88	0.91	0.91	0.88	0.92	0.90	0.86	0.95	0.90	0.94	0.94	0.89	0.89	0.88	0.90	0.88	0.88	0.94	0.90	0.90
Wool	0.75	0.77	0.84	0.84	0.76	0.82	0.77	0.78	0.86	0.82	0.79	0.79	0.83	0.74	0.76	0.83	0.73	0.80	0.84	0.83	0.83
Durables	0.67	0.70	0.84	0.84	0.69	0.85	0.70	0.76	0.89	0.81	0.82	0.65	0.81	0.64	0.69	0.83	0.63	0.70	0.86	0.83	0.83
Energy	0.72	0.73	0.83	0.83	0.73	0.82	0.74	0.77	0.85	0.81	0.78	0.71	0.82	0.69	0.73	0.82	0.69	0.74	0.84	0.82	0.83
Financial	0.64	0.69	0.82	0.81	0.66	0.83	0.67	0.73	0.87	0.78	0.78	0.63	0.79	0.61	0.66	0.80	0.62	0.71	0.84	0.80	0.81
Nondurables	0.72	0.72	0.84	0.84	0.72	0.83	0.74	0.77	0.88	0.81	0.80	0.71	0.82	0.70	0.72	0.83	0.67	0.73	0.85	0.83	0.83
Remittances	0.64	0.69	0.82	0.81	0.66	0.83	0.67	0.73	0.87	0.78	0.78	0.63	0.79	0.61	0.66	0.80	0.62	0.71	0.84	0.80	0.81
Services	0.64	0.69	0.82	0.81	0.66	0.83	0.67	0.73	0.87	0.78	0.78	0.63	0.79	0.61	0.66	0.80	0.62	0.71	0.84	0.80	0.81
Transfers	0.64	0.69	0.82	0.81	0.66	0.83	0.67	0.73	0.87	0.78	0.78	0.63	0.79	0.61	0.66	0.80	0.62	0.71	0.84	0.80	0.81

Table B1: Assumed shares of fixed factors and value added in production

	Fixed factor	Value added
Albania	0.56	0.53
Armenia	0.51	0.50
Bangladesh	0.49	0.46
Cote d'Ivoire	0.59	0.61
Ecuador	0.42	0.46
Guatemala	0.55	0.54
Cambodia	0.63	0.39
Mongolia	0.54	0.36
Malawi	0.51	0.51
Nepal	0.50	0.48
Nigeria	0.81	0.76
Niger	0.59	0.61
Pakistan	0.53	0.50
Panama	0.47	0.58
Peru	0.42	0.46
Rwanda	0.46	0.47
Tajikistan	0.62	0.30
Timor-Leste	0.68	0.45
Uganda	0.47	0.67
Vietnam	0.50	0.36
Zambia	0.49	0.42

Table B2: Output (CRETH) substitution elasticties

	ALB	ARM	BGD	BOL	ECU	GTM	KHM	MWI	NGA	PAK	PAN	PER	UGA	VNM	XEA	XEC	XSE	XSA	XSU	XWF	ZMB
Rice	3.1	2.4	0.4	0.2	0.3	0.6	0.6	1.1	2.3	1.9	0.2	0.3	0.9	1.0	1.0	1.7	2.0	0.3	2.0	1.9	1.2
Wheat	1.4	0.7	1.6	1.0	1.0	3.0	6.3	4.4	2.9	0.6	0.3	1.0	0.4	5.7	1.3	2.1	3.9	0.6	3.5	4.6	0.9
Other grains	0.6	0.2	0.6	0.3	0.2	1.3	0.9	0.3	0.1	0.2	0.7	0.2	0.1	1.4	0.3	0.2	0.6	0.2	0.2	0.1	1.2
Maize	0.4	0.2	0.7	0.2	0.3	0.3	0.4	0.2	0.0	0.2	0.0	0.3	0.3	0.6	0.5	0.2	0.6	0.2	0.1	0.1	0.2
Sorghum	0.8	0.6	0.9	0.3	0.7	0.3	0.4	0.2	0.1	0.2	0.1	0.7	0.1	1.3	0.6	0.1	0.4	1.6	0.4	0.1	1.4
Cassava	1.1	1.1	0.5	0.6	0.1	0.3	0.2	0.1	0.1	0.2	1.5	0.1	0.1	0.6	0.7	0.1	1.0	0.5	2.1	0.1	0.6
Plantains	1.0	1.2	0.2	0.8	0.2	1.0	0.2	0.3	0.1	0.3	1.8	0.2	0.1	0.3	1.8	0.2	1.1	0.5	2.0	0.4	2.3
Potatoes	0.2	0.2	0.2	0.5	0.1	0.4	1.3	0.1	0.1	0.2	1.8	0.1	0.1	0.2	0.5	0.2	1.4	0.3	1.1	0.2	2.1
Vegetables	0.3	0.2	0.5	0.5	1.0	0.6	0.5	1.7	0.1	0.2	1.7	1.0	0.5	0.3	0.3	1.0	0.8	0.6	0.4	0.2	0.9
Fruits	0.3	0.2	0.6	0.5	0.5	0.7	0.4	2.4	0.2	0.3	1.7	0.5	1.0	1.1	0.4	0.6	0.9	0.8	0.3	1.2	1.4
Other oil seeds	0.3	0.3	1.1	1.1	0.2	1.1	0.5	1.1	1.3	1.0	0.0	0.2	0.8	1.6	0.9	2.0	1.0	1.3	3.1	0.8	1.5
Peanuts	0.3	0.2	0.7	1.2	0.6	0.5	0.2	0.9	0.1	1.1	0.4	0.6	0.2	1.3	1.9	0.2	1.0	2.2	3.1	0.3	1.6
Soybeans	0.1	0.2	1.7	1.6	1.2	0.7	0.3	1.8	0.1	1.7	0.4	1.2	0.1	0.5	0.6	0.6	0.7	0.5	3.0	1.1	2.0
Raw sugar	0.3	0.1	0.3	0.2	0.0	0.5	0.1	0.4	0.1	0.1	0.2	0.0	0.8	0.1	0.1	0.2	0.1	0.3	0.3	0.1	1.6
Plant based fiber	2.0	0.2	0.8	2.3	0.7	1.7	0.9	2.7	1.4	0.5	0.7	0.7	2.4	1.9	0.1	1.4	1.8	0.4	1.6	3.4	2.4
Other crops	1.0	1.1	0.5	0.3	0.8	2.5	0.3	4.3	3.2	0.6	1.2	0.8	3.7	1.9	1.4	3.2	0.8	1.2	0.6	2.1	0.3
Coffee & tea	0.2	0.9	0.5	0.2	1.3	2.0	0.5	4.5	3.7	0.4	0.1	1.3	2.8	1.7	2.0	0.8	0.9	1.4	2.5	3.6	0.5
Tobacco	0.3	0.3	0.3	2.6	0.1	1.5	0.4	1.5	3.4	0.0	2.7	0.1	1.9	1.3	1.1	0.2	0.9	0.9	1.1	3.1	0.8
Other bovines	1.3	0.2	0.1	0.1	1.7	0.1	0.9	0.1	0.1	0.2	0.5	1.7	0.2	0.2	0.5	0.6	1.1	0.1	0.2	0.2	0.1
Cattle	0.4	0.3	0.1	0.1	0.1	0.3	0.3	0.5	0.1	0.1	0.1	0.1	0.3	0.2	2.0	1.0	0.7	2.8	0.2	0.3	1.2
Other animal products	1.9	0.3	0.9	0.3	0.5	1.6	1.6	1.9	1.9	1.5	1.5	0.5	1.8	1.4	1.4	0.7	1.6	1.7	0.4	0.2	1.5
Eggs	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.3	0.1	0.2	0.2	0.2	0.4	0.3	0.5	0.2	0.6	0.3	0.2	0.3	0.3
Fowl	1.8	1.2	0.4	0.2	0.2	0.3	0.4	1.0	0.2	0.5	0.1	0.2	1.2	0.9	1.1	1.7	0.4	0.4	0.6	0.6	0.6
Swine	0.6	1.9	1.6	0.1	0.1	0.2	0.1	0.2	0.2	1.5	1.7	0.1	0.2	0.2	0.7	0.2	1.4	0.9	1.1	0.2	1.1
Raw milk	0.2	0.0	0.1	0.1	0.2	0.2	1.1	0.2	0.1	0.1	0.0	0.2	0.2	0.5	0.2	0.2	1.3	0.2	0.3	1.0	0.2
Wool	1.2	0.1	10.4	0.5	0.8	3.4	1.9	4.1	3.5	0.4	0.5	0.8	2.6	0.9	2.8	0.4	6.0	8.2	0.9	3.8	0.3
Forestry	0.3	0.2	0.1	0.1	0.2	0.6	0.2	0.2	0.6	0.6	0.7	0.2	0.3	0.6	0.3	0.3	0.3	0.3	0.9	0.8	0.2

	ALB	ARM	BGD	BOL	ECU	GTM	KHM	MWI	NGA	PAK	PAN	PER	UGA	VNM	XEA	XEC	XSE	XSA	XSU	XWF	ZMB
Fish	0.3	0.3	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.1	0.2	0.2	0.1	0.2	0.1
Other processed bovine meat	0.5	1.4	4.2	0.4	0.3	0.8	7.5	0.3	0.6	0.8	7.2	0.3	0.5	1.4	2.6	2.2	3.8	1.0	0.5	0.6	0.3
Processed beef	0.6	0.8	4.0	0.2	0.3	0.4	0.4	0.3	0.7	0.5	0.5	0.3	0.3	0.2	3.6	0.5	1.7	1.0	0.4	0.8	0.2
Other processed meat	4.1	6.5	8.3	0.4	6.8	5.5	8.3	4.0	0.8	3.3	8.1	6.8	1.6	1.7	2.4	0.4	7.4	4.3	1.2	1.7	0.3
Processed poultry	1.4	3.1	5.9	0.2	0.3	0.5	0.7	0.4	0.9	0.4	0.4	0.3	0.6	0.3	4.2	0.6	2.0	3.9	1.2	2.3	0.3
Processed pork	1.2	2.2	8.4	0.2	0.5	1.5	0.3	0.2	1.1	7.9	1.9	0.5	0.4	0.6	2.8	1.1	8.0	4.2	2.1	3.3	0.5
Oils and fats	3.3	2.3	2.4	2.8	1.2	2.8	1.9	3.7	1.9	1.4	0.5	1.2	4.8	2.9	2.1	1.4	3.3	2.5	4.3	3.4	1.4
Dairy	0.5	0.4	1.4	0.8	0.6	1.0	3.4	1.1	4.0	0.3	0.7	0.6	1.2	2.3	2.6	2.8	3.0	1.6	0.6	2.4	2.5
Processed sugar	3.2	1.1	0.7	1.1	0.3	1.3	0.4	4.4	4.3	0.3	2.4	0.3	0.7	0.3	1.9	1.5	1.2	0.7	2.8	4.2	3.3
Other food	1.4	0.9	1.0	1.5	1.6	0.9	1.0	1.2	1.8	1.0	1.7	1.6	2.7	2.8	1.0	0.7	1.7	1.4	1.5	2.5	0.4
Beverages & tobacco	1.3	1.0	0.2	0.3	0.2	0.5	1.2	0.2	0.7	0.2	0.7	0.2	0.2	0.5	0.7	0.2	1.1	0.8	0.6	0.7	0.2
Nondurables	2.9	7.4	4.4	3.7	4.5	3.8	9.3	3.3	3.0	2.9	3.4	4.5	4.6	12.6	5.6	2.9	6.0	8.5	7.2	5.1	2.0
Durables	4.3	3.8	2.4	5.2	1.1	2.6	4.9	3.1	3.5	4.5	3.5	1.1	3.5	4.7	3.1	3.8	8.7	3.5	5.4	7.0	3.0
Svces	1.2	1.0	0.5	0.5	0.8	0.3	1.0	0.3	1.8	0.4	1.5	0.8	0.9	1.0	1.1	0.8	0.9	0.6	0.6	0.6	0.5
Energy	2.7	3.8	0.4	1.6	2.3	2.8	3.0	2.6	0.5	1.6	3.9	2.3	1.7	1.7	2.8	1.8	0.8	1.3	0.8	2.3	1.5

Figure 1: Regions defined and used in this work

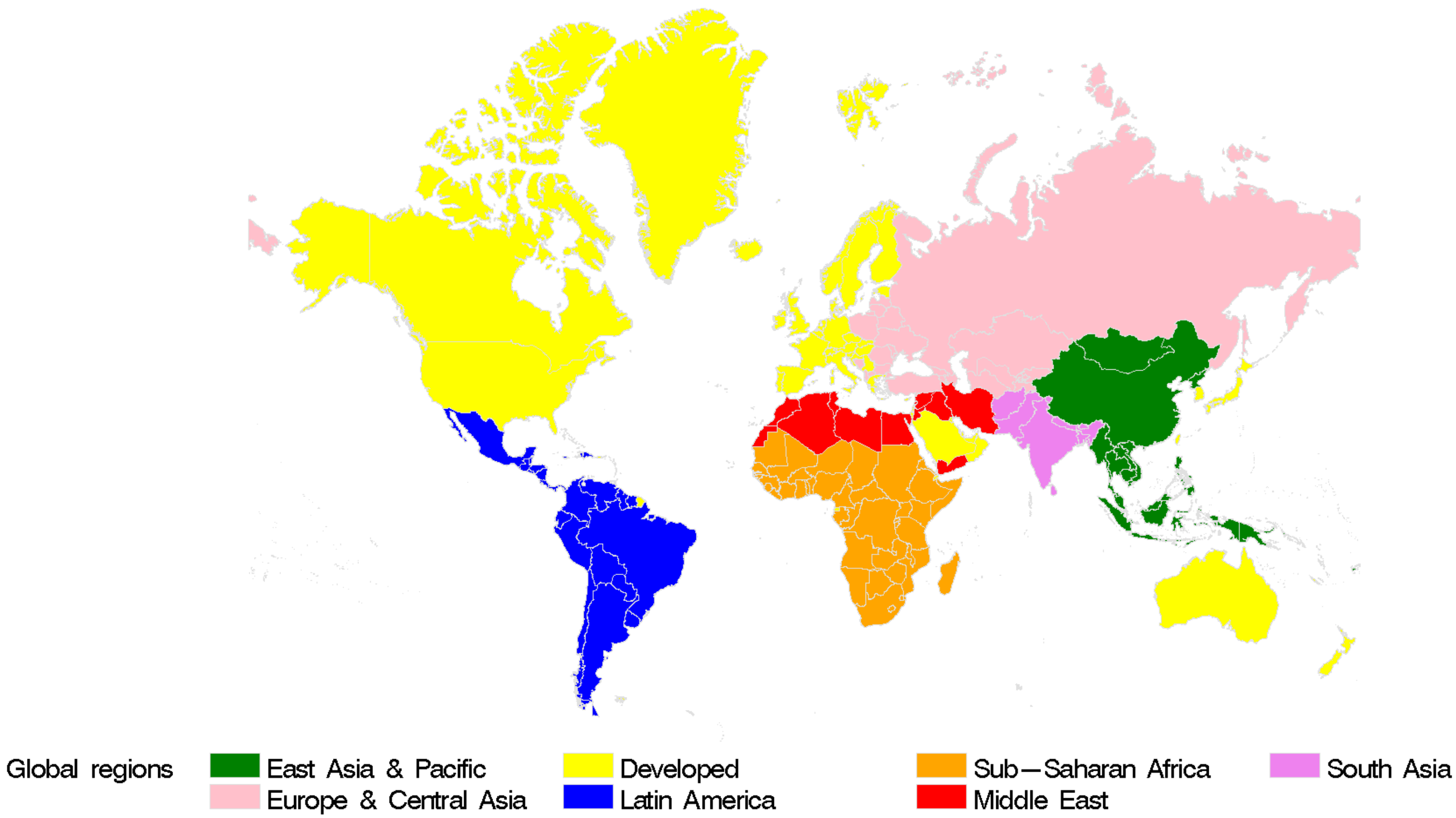
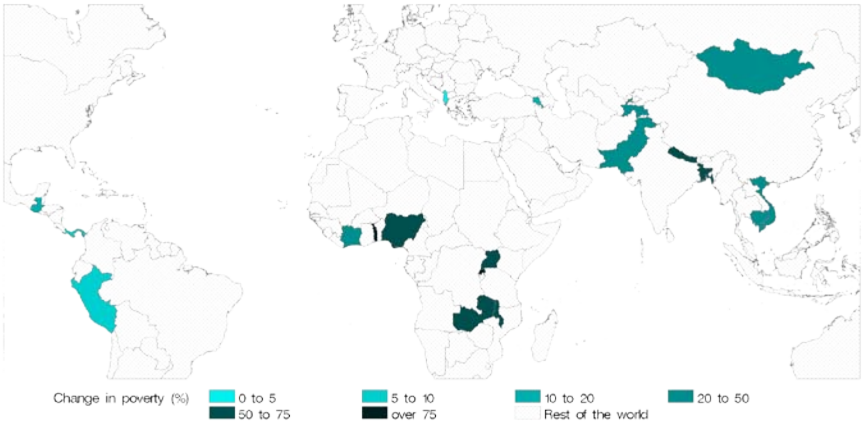
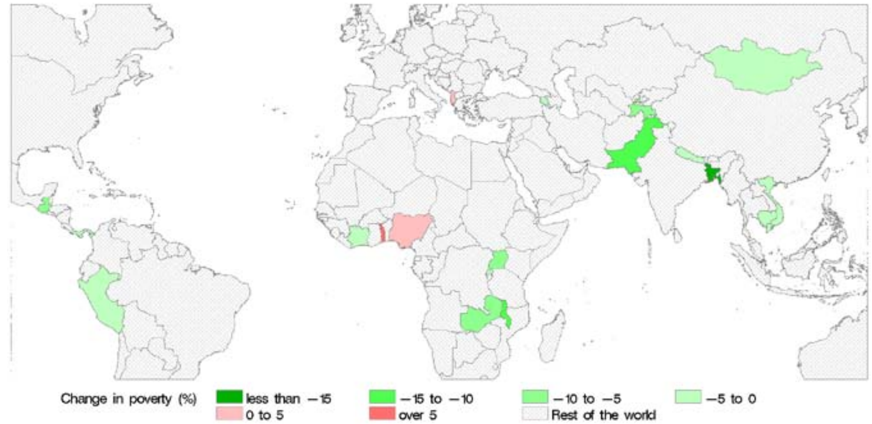


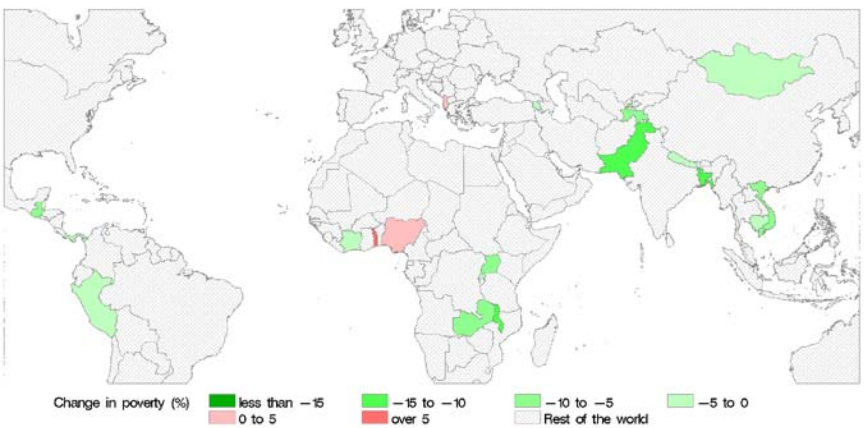
Figure 2: Change in poverty rates (in percentage points) by scenario



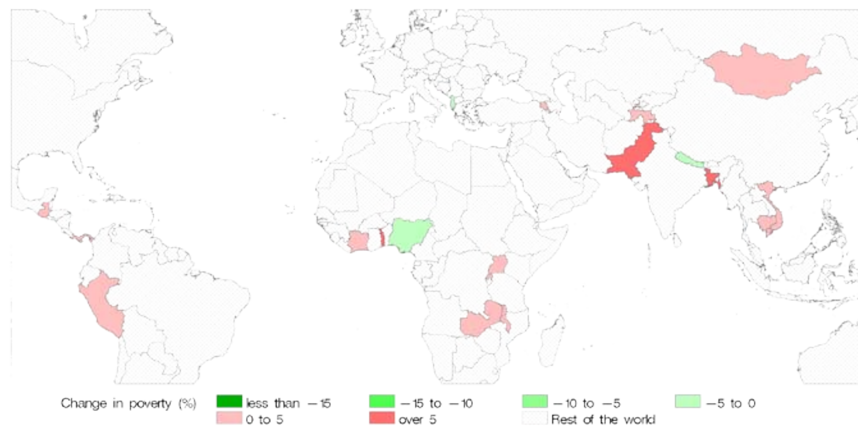
Poverty rates



Higher agric productivity



Higher agric productivity in developing countries



Protection

Figure 3: Poverty impacts of raising agricultural productivity by 1 percentage point over 40 years (percentage point changes in average poverty rate; range of one standard deviation) (Scenario: 1 pct growth in global TFP over 40 years)

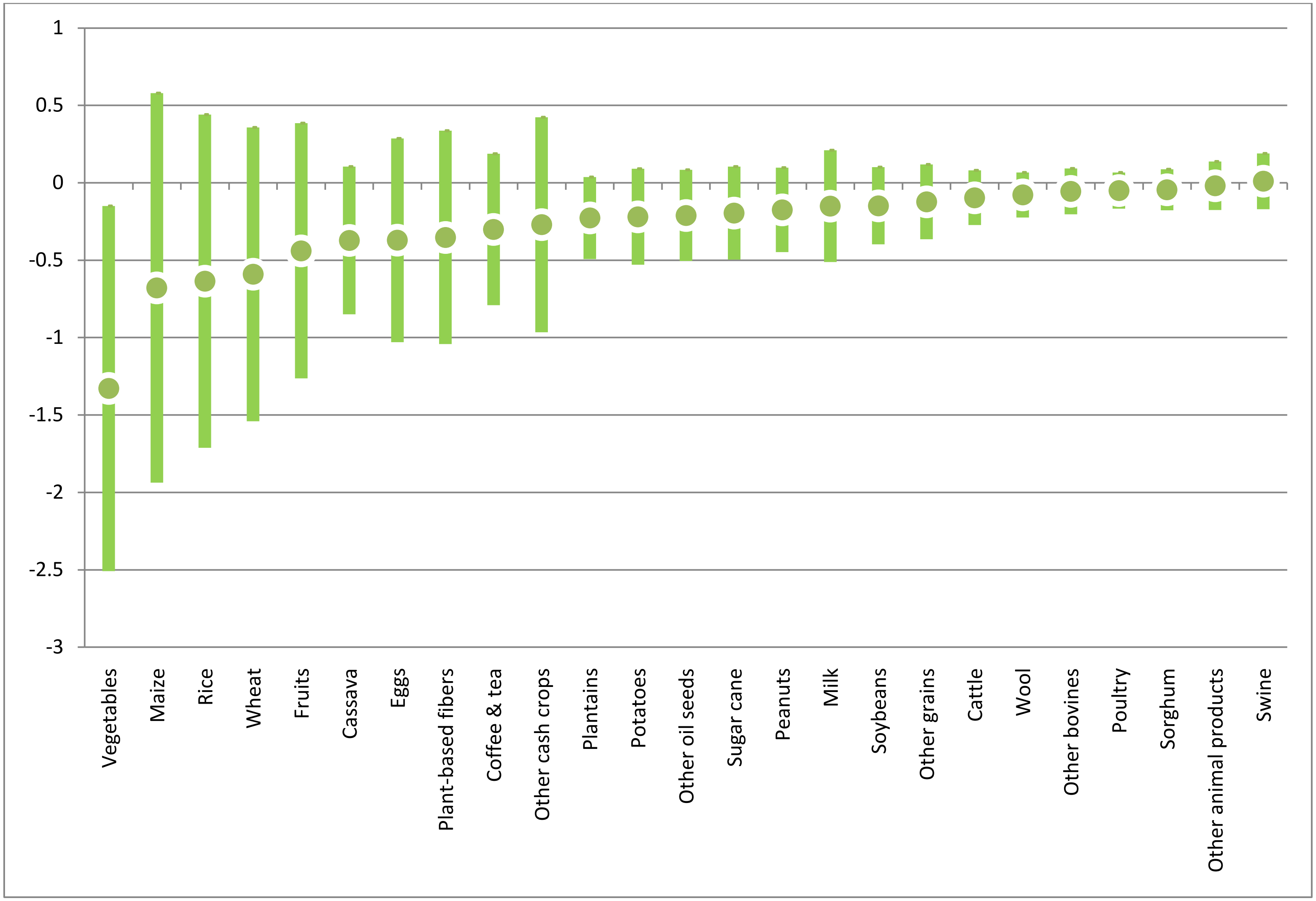


Figure 4: Decomposition of poverty results with respect to consumers and producers for some key commodities (percentage point changes in average poverty rate; range of one standard deviation)

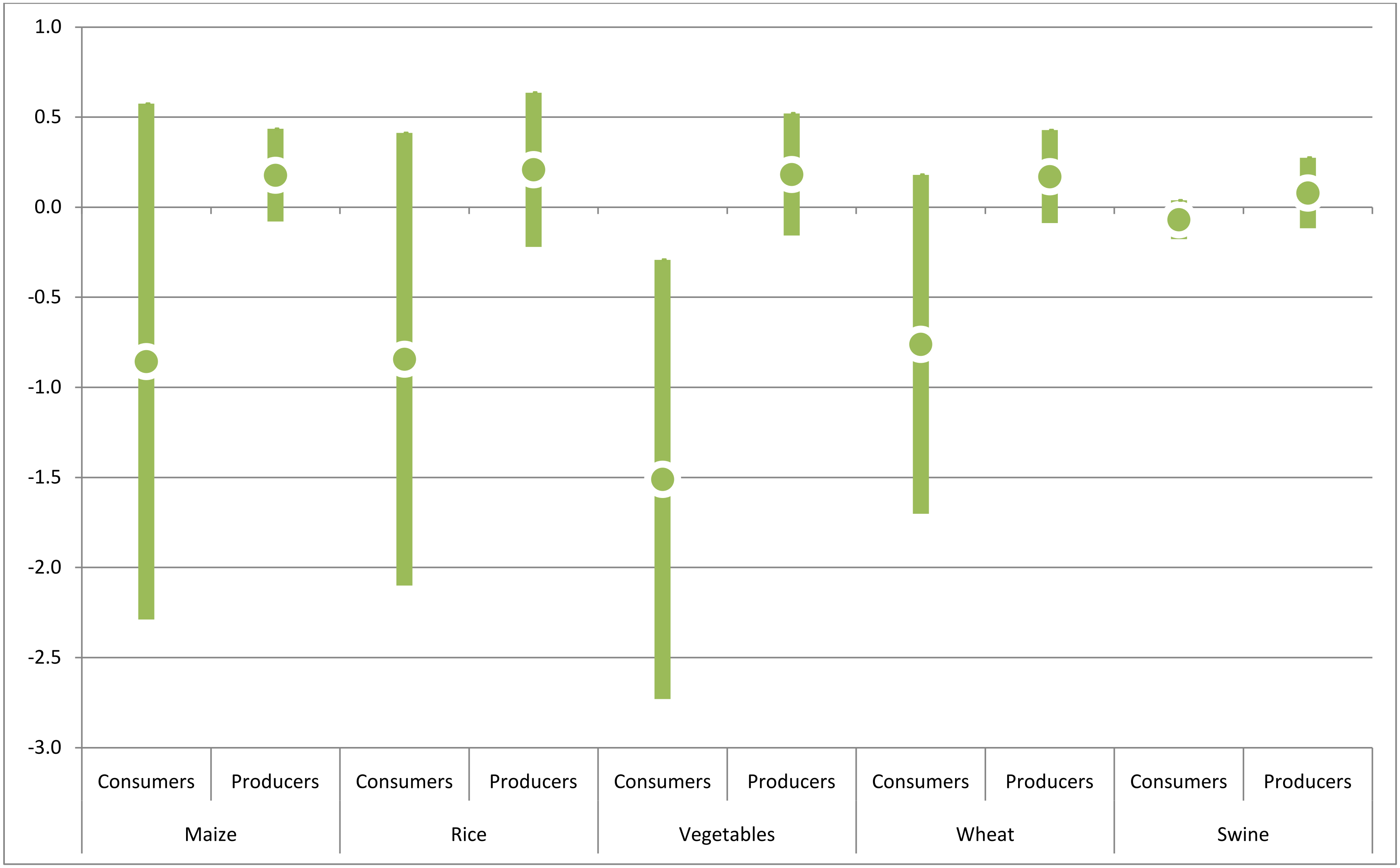


Figure 5(a): Average poverty changes (pct) of direct and indirect productivity impacts for various rates of adoption of agricultural technology by farmers in developing countries (1 pct improvement in TFP for forty years)

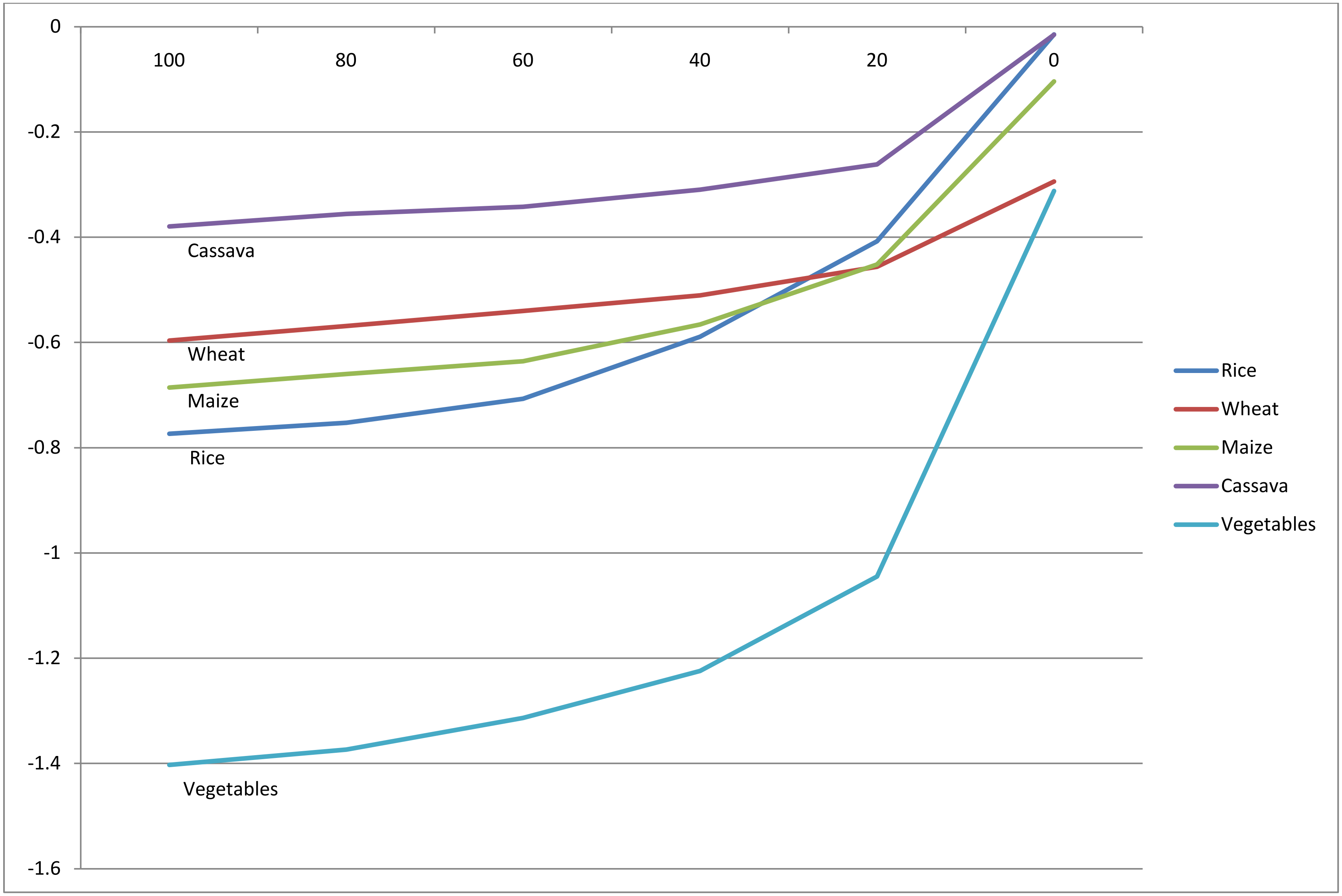


Figure 5(b): Average poverty changes (pct) of direct productivity impacts for various rates of adoption of agricultural technology by farmers in developing countries (1 pct improvement in TFP for forty years)

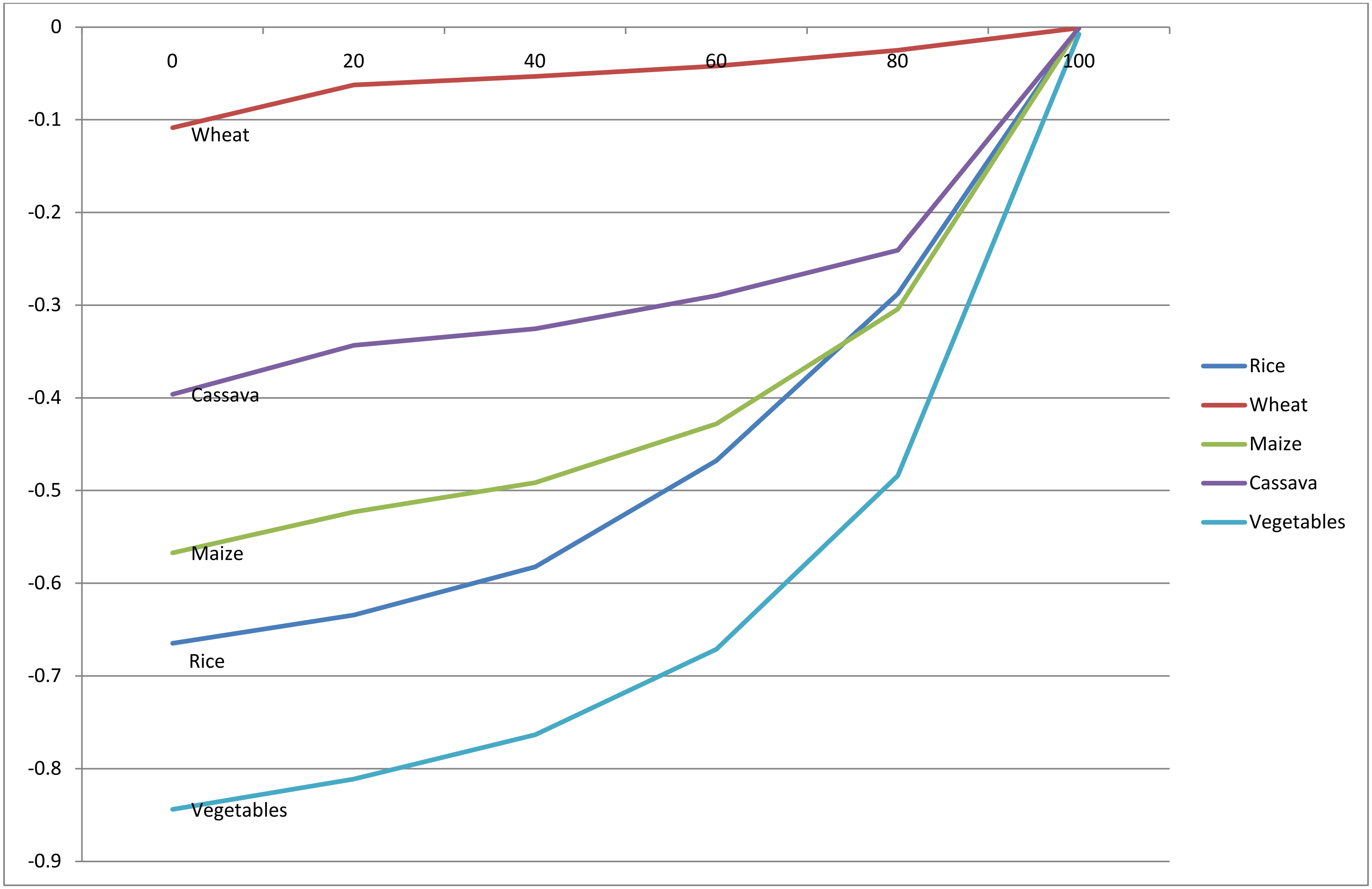


Figure 6(a): Average poverty changes (pct) of direct and indirect productivity impacts for various rates of adoption of agricultural technology by farmers in developing countries (pct) (Scenario: 1 pct improvement in output productivity for forty years)

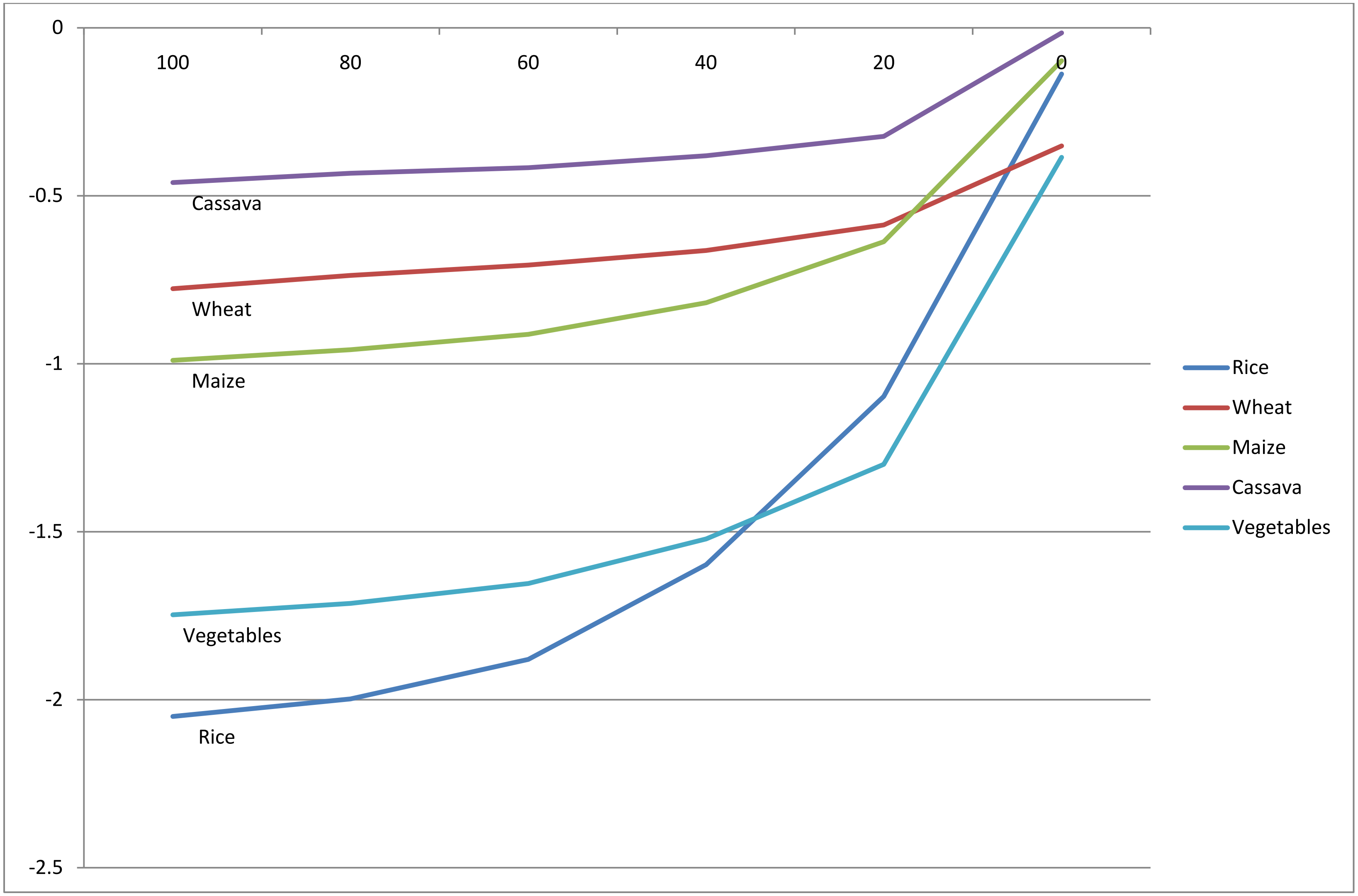


Figure 6(b): Average poverty changes (pct) of direct productivity impacts for various rates of adoption of agricultural technology by farmers in developing countries (pct) (Scenario: 1 pct improvement in output productivity for forty years)