PROMOTING GLOBAL AGRICULTURAL GROWTH AND POVERTY REDUCTION

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ABSTRACT

Constraints on resources, growth in demand, and a slowdown in agricultural productivity raise concerns that food prices may rise substantially over the next decades. The impacts of such higher prices on the poor and the required mitigating policy responses to this problem remain unclear. This paper uses a global general equilibrium model, projections of global growth and microeconomic household models, to project potential implications for incomes, food production and poverty. We find that higher agricultural productivity would generally lower poverty, with different impacts depending where the productivity growth occurs, while protection policies that reduce imports would generally raise poverty.

Key words: poverty, growth, projections

1. 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 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.

2. 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). The projections of the USCB are especially valuable because they have been calculated for all economies.

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, labour force accumulation and estimates of savings rates to produce long-run projections of GDP, labour 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. 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 labour and output can be expected to create pressure for resources to move into more capital-intensive sectors, and out of labour-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).

3. 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 potential adverse impacts of lower commodity prices on the earnings of farmers, and those who earn their incomes as agricultural labourers. As Matsuyama (1992) has pointed out, this is unlikely to be a problem when considering a change in agricultural productivity in a single, small, open country. Higher productivity in the agricultural sector of an open economy is likely to stimulate output from the sector as the increased profitability of the sector causes resources to be pulled in and output to rise through the combined effect of higher output per unit of input, and greater input use.

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 cause large declines in prices, which cause producers to reduce their allocation of inputs to 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 labour 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.

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 labour 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 favourable, 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.

4. MODEL

4.1. Global Model

Our global simulation is based on the latest (version 7 pre-release 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). 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 (split into 37 commodities), 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.

<<Figure 1 about here>>

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 labour 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.

4.2. 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 recent household surveys from twenty developing countries that span the developing world (Table 1).

<<Table 1 about here>>

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, including any own-produced consumption, was separated into seven broad categories: 37 agricultural (food) products, non-durables, energy goods, durables, services, financial expenses, and taxes and remittances paid by the household.

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, labour expenses, energy consumption etc.)

In the model, 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 labour 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.

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 labour 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:

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

Using a Taylor series expansion, we obtain a second-order estimate of the change in the cost of utility as

(2) $$\Delta e = \left(\boldsymbol{p} \cdot \boldsymbol{x}^T \widehat{\boldsymbol{p}} + \frac{1}{2} \cdot [\boldsymbol{p} \cdot \boldsymbol{x} \cdot \widehat{\boldsymbol{p}}]^T \times \epsilon \times \widehat{\boldsymbol{p}}\right),$$

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. The calculation of matrix ϵ is shown in Appendix A.

On the supply side, we express the change in profits following a change in prices using a Taylor expansion:

(3) $$\Delta\pi = \pi \cdot \left([\boldsymbol{p} \cdot \boldsymbol{q}]^T \widehat{\boldsymbol{p}} + \frac{1}{2} \cdot [\boldsymbol{p} \cdot \boldsymbol{q} \cdot \widehat{\boldsymbol{p}}]^T \times \mu \times \widehat{\boldsymbol{p}}\right),$$

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.

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. 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 labour income $\Delta l(p_w)$ as

(4) $$\Delta l(p_w) = l \cdot p_w \cdot \hat{p}_w,$$

where $l \cdot p_l$ is the observed labour income. Our treatment assumes that the total amount of labour supplied by the household is fixed while the quantity supplied to the household's own business varies.

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). The poverty lines used in our calculations, reported in Table 1, were calculated using our household surveys in conjunction with the published poverty rates at a $1.25-a-day poverty line.[1]

5. Scenarios

5.1. Projections

Using projections described in the second section, we formulated a baseline scenario. As is evident in Table 2, these projections imply some noticeable differences between the growth rates of population and of the labour force at the regional level because of changes in dependency ratios. 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-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).

<<Table 2 about here>>

While the population projections we use are comprehensive, covering 227 countries and territories, the projections of labour, 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 neighbouring countries to fill these gaps. The aggregate estimates of GDP growth for the regions used in our model are reported in Table 2.

[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.

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 sharp deterioration from past rates of agricultural productivity growth. In our projections, we have not explicitly considered the role of demand for food for biofuels, but this could raise the total demand for food substantially.

5.2. Possible policy responses

Our primary policy response scenario involves improvements in agricultural productivity. We firsts consider changes in agricultural productivity globally, and then consider the impacts of increases in agricultural productivity in developing countries alone. This 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.

6. RESULTS

6.1. 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.

<<Table 3 about here>>

As reported in Table 3, 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.

6.2. 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 Tables 4 and 5. For a global increase in farm productivity of 1 percent per year, 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.

<<Table 4 about here>>

The third section 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 4, 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 'Developing column.' These are generally broadly in line with those for the world as a whole, and involve increases averaging 31 percent.

<<Table 5 about here>>

In Table 5 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 increases the domestic price of agricultural output by 67 and 138 percent, respectively. Other regions require significantly lower protection which reduces imports more without raising the domestic prices much.

<<Table 6 about here>>

To understand the implications of our global and developing-country policy scenarios at the household level, 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 6. The first set of columns of the table shows the original poverty rate (at 1.25 USD per day per person) as reported in each sample country. We list both the nation-wide poverty rates and those for rural poverty.

The next set of columns shows the poverty impacts of the policy scenarios as a percentage point change from the 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 later.

In the pair of columns in Table 6, 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 essentially the same 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 third pair of columns in Table 6 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 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 2.4 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.

<<Table 7 about here>>

To understand this poverty reduction, we further decompose it in Table 7 with respect to individual sectoral impacts. The sixth column of Table 7, for example, shows that the average reduction in poverty by 5.4 percentage points in the high agricultural productivity growth scenario is mainly caused by the impact of the agricultural prices on consumption—which result in an average reduction in poverty of 5.6 percentage points. The second most important impact appears to come from rising wages for labour 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 3.0 percentage points—a change linked to the increase in wage rates.

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 7, we are now in the position to explain the strange case of Nigeria and Albania, the two countries where the poor appear to lose out from the higher productivity gains scenario. 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 in concert with those of Montalvo and Ravallion (2009) that have shown that increases in agricultural yields were key drivers of poverty reduction in China in the period of 1983–2001. Similarly, Minten and Barrett (2008) have found a link between improved agricultural efficiency through lower prices and higher wage incomes on poverty. 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.

6.3. Role of agricultural productivity in poverty reduction

The poverty results of the three scenarios presented in this section suggest the 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. How much effort should be devoted to extending findings to the smallest—and possibly least easy-to-access producers?

To investigate this matter further, we calculate poverty impacts for a set of higher agricultural productivity scenarios—similar to the one presented earlier—where we raise 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. Because we are also interested in the distributional impacts of the raised productivity, for each scenario we calculate not only the overall poverty impact of raising a productivity in a particular commodity, but also another set of impacts if we assumed that only some farms receive the benefit of higher productivity. More specifically, for each scenario we assume that a certain portion of the smallest farms does not benefit at all from higher agricultural productivity, and we further assume that these farms are only affected by the changes in the prices.

<<Figure 2 about here>>

Because of the computational complexity of calculating all sets of poverty impacts, we first identify those agricultural commodities that have the greatest potential of reducing poverty through their direct impacts on farmers' effective output prices. We calculate these impacts by assuming a 100 percent output productivity gain and then calculate the result of that change only for poverty reduction. Additionally, we calculate these impacts for different values of technology adoption among the smallest and poorest households. We present these results in Figure 2 which identifies the top seven commodities with the greatest poverty reducing potential at the global level. Looking at the figure, we can see that a 100 percent increase in the output productivity of rice has the greatest direct impact on poverty, reducing it by about 2.7 percentage points. However, when the rate of adoption drops to 0.8—which means that only the top 80 percent of farms by size adopt the new technology—the poverty reducing effect begins to decline When the adoption rate drops to zero, all poverty impacts naturally disappear for all commodities. Figure 2 makes another interesting point by showing rank reversal with regard to the rate of adoption: while rice seems to be most poverty reducing with a 100-percent adoption rate, its effect is superseded by that of vegetables if adoption rate falls below 50 percent.

In our final analysis of the importance of individual commodity productivity gains and the adoption rates, we use a set of simulations similar to that of higher agricultural productivity growth, except that we raise productivity for each commodity one at a time. We choose two commodities to analyze the comprehensive poverty impacts of raising agricultural productivity and its level of adoption: rice, which represents a commodity which has been identified in our earlier exercise as having high potential for direct poverty reduction, and wheat, which appears to be linked little directly to poverty reduction through providing its producers with higher effective prices.

<<Table 8 about here>>

To help with the analysis, in Table 8, we present a set of impacts of raising productivity in both of these commodities for a range of adoption rates. In this table, we show poverty impacts of raising global total factor productivity by 1 percent over the period of 40 years for rice and wheat. For each adoption rate, we present a decomposition of the poverty results with respect to the differential impacts of the changes in agricultural and food prices and productivity on the consumers and producers. We also include a column 'other impacts' which contain the rest of the impacts such as changes in wages and prices of other goods which play little role in this experiment. Similarly to our earlier decomposition in Table 7, the impacts of improving global agricultural technology are favourable for the poor through lower prices; they are unfavourable to the producers who face significant drops in the market price only partially compensated by their own effective output price gains. Finally, the sign of the rest of the impacts is small and ambiguous and it depends on the particular production structure.

Table 8 is particularly illuminating in showing the interplay of two important components of poverty reduction through higher agricultural productivity: first, we can see that a commodity, such as wheat, may show little change in its effective output prices, but it may still have a considerable impact on poverty through favourable price impacts; in such a case, the rate of adoption plays little role in the overall poverty reducing impacts. Second, we observe that for some commodities, for example rice, the adoption rate is vital because a significant portion of the benefit to the poor comes from the benefits to producers of higher productivity.

7. 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, labour, capital and productivity, and modelled 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 has a favourable impact on poverty reduction. However, our analysis also shows that nearly all of the positive impacts come from the favourable reductions in the cost of food consumption; the direct impact of improved agricultural productivity is often negative for farmers who get trapped in the 'treadmill' problem when their own productivity improvement is insufficient to offset the negative impact of falling producer prices.

If developing countries respond to the comment climate of concern about food security to raise protection on agricultural commodities, the implications on poverty are likely to be unfavourable—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.

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. However, we also demonstrate that strong poverty reduction may come from other commodities, such as wheat, whose improved productivity benefits consumers indirectly through consumer prices more than the producers through higher profits.

Finally, our work shows that while it highly desirable that improvements in agricultural productivity be extended to the smallest farmers, it turns out 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 benefit is derived through favourable 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.

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 :

(A.1) $$\epsilon_{i,j} = \left(\alpha_i + \alpha_j - \boldsymbol{\sigma}^T \times \boldsymbol{\alpha}\right)\sigma_j,$$

when $i \neq j$, and

(A.2) $$\epsilon_{i,j} = \left(\alpha_i + \alpha_j - \boldsymbol{\sigma}^T \times \boldsymbol{\alpha}\right)\sigma_j - \alpha_i \frac{\sigma_j}{\sigma_i},$$

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. 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 behaviour; 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 labour.

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 (labour) 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

(A.3) $$\forall k: \hat{q}_k\text{-}\hat{q}_o = \sigma_{T_i}(\hat{p}_k - \hat{p}_o),$$

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:

(A.4) $$\hat{q}_o - \hat{q}_v = \sigma_V(\hat{p}_o - \hat{p}_v) \text{ and } \hat{q}_o - \hat{q}_i = \sigma_V(\hat{p}_o - \hat{p}_i).$$

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

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

(A.5) $$\hat{q}_v - \hat{q}_f = \sigma_F(\hat{p}_v - \hat{p}_f)$$

(A.6) $$\hat{q}_v - \hat{q}_m = \sigma_F(\hat{p}_v - \hat{p}_m)$$

With the zero-profit condition represented by $\hat{\mathrm{p}}_\mathrm{v} = \mathrm{s_f}\hat{p}_\mathrm{f} + \mathrm{s_m}\hat{p}_\mathrm{m}$, where $\mathrm{s_f}$is the share of the fixed factor in the value-added and $\mathrm{s_m}$ 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 ($\hat{\mathrm{q}}_\mathrm{f} = 0$).

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.

(A.7)

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

(A.8)

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

$$+\sigma_V\begin{bmatrix} -\frac{s_k^* s_i}{s_v} & -\frac{s_l^* s_i}{s_v} & 0 & \frac{s_i}{s_v} \\ -\frac{s_k^* s_i}{s_v} & -\frac{s_l^* s_i}{s_v} & 0 & \frac{s_i}{s_v} \\ 0 & 0 & 0 & 0 \\ -\frac{s_k^*}{s_v} & -\frac{s_l^*}{s_v} & 0 & \frac{1}{s_v} \end{bmatrix}+\sigma_F\begin{bmatrix} -\frac{s_k^* s_m}{s_f s_v} & -\frac{s_l^* s_m}{s_f s_v} & \frac{s_m}{s_f} & \frac{s_i s_m}{s_f s_v} \\ -\frac{s_k^* s_m}{s_f s_v} & -\frac{s_l^* s_m}{s_f s_v} & \frac{s_m}{s_f} & \frac{s_i s_m}{s_f s_v} \\ -\frac{s_k^*}{s_f s_v} & -\frac{s_l^*}{s_f s_v} & \frac{1}{s_f} & \frac{s_i}{s_f s_v} \\ -\frac{s_k^* s_m}{s_f s_v} & -\frac{s_k^* s_m}{s_f s_v} & \frac{s_m}{s_f} & \frac{s_i s_m}{s_f s_v} \end{bmatrix}$$

The values of the production elasticity matrix were calculated using the formula above. The values of σ_F and $\sigma_V$were obtained from the GTAP parameter file. 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.

REFERENCES

Albania (2005). Living Standards Measurement Survey. The World Bank and the Albania Institute of Statistics (INSTAT).

Alston Julian M., Jason M. Beddow, and Philip G. Pardey (2009). Mendel versus Malthus: Research, Productivity and Food Prices in the Long Run. Staff Paper P09-1, University of Minnesota

Alston, J., Marra, M., Pardey, P. and Wyatt, T. (2000). Research returns redux: a meta analysis of returns to agricultural R&D *Australian Journal of Agricultural and Resource Economics* 44(2):185-215.

Bangladesh (2000). Household Income-Expenditure Survey. Bangladesh Bureau of Statistics Parishankhan Bhaban, E-27/A, Agargaon, Sher-E-Bangla Nagar.

Cambodia (2003). Household Socio-economic Survey. Royal Government of Cambodia, Ministry of Planning, National Institute of Statistics.

Côte d'Ivoire (2002). Enquete Niveau de Vie des Menages. Instutut National De La Statistique. Cote d'Ivoire.

Cranfield, J., Preckel, P.,Hertel, T., (2007). Poverty analysis using an international cross-country demand system. Policy ResearchWorking Paper 4285,World Bank.

Bank, Washington, DC.Datt, G. and Ravallion, M. (1998). Farm productivity and rural poverty in India. *Journal of Development Studies* 34(4):62-85.

Evans, A. (2009). The feeding of the nine billion: global food security for the 21st Century. Chatham House Report, London.

Fischer, R. Byerlee, D. and Edmeades, G. (2009). Can technology deliver on the yield challenge to 2050? Paper for presentation to High Level Expert Forum on How to Feed the World in 2050, Food and Agriculture Organization, Rome, October 12-3.

Fuglie, K. (2008). Is a slowdown in agricultural productivity growth contributing to the rise in agricultural prices? *Agricultural Economics* 39:431-44.

Gehlhar, M., Hertel, T. and Martin, W. (1994) 'Economic growth and the changing structure of trade and production in the Pacific Rim. *American Journal of Agricultural Economics* 76:1101-10.

Guatemala (2006). Encuesta Nacional de Condiciones de Vida', Instituto Nacional de Estadistica. Guatemala.

Hanoch, Giora (1975). Production and demand models with direct or indirect implicit additivity. Econometrica, 43(3):395{419, 1975. ISSN 00129682. URL http://www.jstor.org/stable/1914273.

Hertel, Thomas (ed.) (1997). *Global Trade Analysis: Modeling and Applications*, Cambridge University Press, New York.

Ivanic, M. and Martin, W. (2008). Implications of higher global food prices for poverty in low-income countries. *Agricultural Economics* 39:405-16.

de Janvry, A. and Sadoulet, E. (1998), World poverty and the role of agricultural technology. *Journal of Development Studies* 38(4):1-26.

Lanjouw, P. and Ravallion, M. (1995). Poverty and Household Size. *The Economic Journal* 105(433):1415-1434.

Malawi (2004). Second Integrated Household Survey. Malawi Government National Statistical Office. Malawi.

Martin, W. and Mitra, D. (2001). Productivity growth and convergence in agriculture and manufacturing. *Economic Development and Cultural Change* 49(2):403-23.

Martin, W. and Warr, P. (1993) Explaining agriculture's relative decline: a supply side analysis for Indonesia. *World Bank Economic Review* 7(3):381-401.

Matsuyama, K. (1992). Agricultural productivity growth, comparative advantage and economic growth. *Journal of Economic Theory* 58(2):317-34.

van der Mensbrugghe, D., Osorio-Rodarte, I., Burns, A. and Baffes, J. (2009) Macroeconomic environment, commodity markets: A longer term outlook. Paper for presentation to High Level Expert Forum on How to Feed the World in 2050, Food and Agriculture Organization, Rome, Italy.

Minten, Bart, Christopher B. Barrett (2008). Agricultural Technology, Productivity, and Poverty in Madagascar. World Development Vol. 36, No. 5, pp. 797–822.

Montalvo, Jose G., Martin Ravallion (2009). The Pattern of Growth and Poverty Reduction in China. Policy Research Working Paper 5069, The World Bank Development Research Group, Washington, USA.

Msangi, S. and Rosegrant, M. (2009). World Agriculture in a Dynamically-Changing Environment: IFPRI's Long-term Outlook for Food and Agriculture under Additional Demand and Constraints. Paper for presentation to High Level Expert Forum on How to Feed the World in 2050, Food and Agriculture Organization, Rome, Italy.

Mulder, Tammany J. (2002). Accuracy of the U.S. Census Bureau National Population Projections and Their Respective Components of Change. Population Division, U.S. Census Bureau, Working Paper Series No. 50.

Pakistan (2005). Pakistan Social and Living Standards Measurement Survey. Government of Pakistan, Pakistan.

Peru (2007). Encuesta Nacional de Hogares. Instituto Nacional de Estadistica E Informatica, Peru.

Poncet, Sandra (2006), The Long Term Growth Prospects of the World Economy: Horizon 2050. CEPII, Working Paper No 2006-16.

Rwanda (2005). Integrated Household Living Conditions Survey. Ministry of Finance and Economic Planning, Statistics Department, Rwanda.

Rybczynski, T. (1955). Factor endowments and relative commodity prices. *Economica* 22(4):336-41.

Taylor, S. (2008). If the CAP fits, the EU will grow. EuropeanVoice.com, 31 January.

Timor-Leste (2000). Poverty Assessment Project. National Planning and Development Agency Census and Statistics Unit, Timor Leste.

Uganda (2005). Socio-Economic Survey. Uganda Bureau of Statistics, Uganda.

Vietnam (2004). Household Living Standard Survey. General Statistical Office, Vietnam.

Table 1: Household surveys included in this study

Country	Survey name	Year	Number of households	Rural households	Poverty rate	Rural poverty rate
Albania	Living Standards Measurement Survey	2005	1,671	1,447	0.8	0.9
Armenia	Integrated Survey of Living Standards	2005	6,815	1,728	10.6	14.5
Bangladesh	Household Income-Expenditure Survey	2000	7,440	5,040	40.2	46.1
Cambodia	Household Socio-economic Survey	2003	14,984	11,990	50.5	59.7
Cote d'Ivoire	Enquete Niveau de Vie des Menages	2002	10,798	5,819	23.3	29.3
Guatemala	Encuesta Nacional de Condiciones de Vida	2006	13,686	7,878	12.6	17.2
Malawi	Second Integrated Household Survey	2004	11,280	9,840	73.9	77.2
Mongolia	Household Income and Expenditure Survey	2002	3308	1,457	22.4	23.6
Nepal	Nepal Living Standards Survey II	2002	5071	3,655	55.1	67.0
Niger	Enquete National sur Le Budget et la Consommation des Menages	2007	4,000	2,084	65.9	83.5
Nigeria	Nigeria Living Standards Survey	2003	19,121	14,481	64.4	70.2
Pakistan	Pakistan Social and Living Standards Measurement Survey	2005	15,453	9,213	22.6	26.4
Panama	Encuesta de Niveles de Vida	2003	6362	2,944	9.4	18.2
Peru	Encuesta Nacional de Hogares	2007	22,201	8,639	7.9	17.6
Rwanda	Integrated Household Living Conditions Survey	2005	6,900	5,280	76.6	88.2
Tajikistan	Living Standards Measurement Survey	2007	4644	2,984	21.5	22.0
Timor-Leste	Poverty Assessment Project	2000	1,800	1,098	52.9	64.8
Uganda	Socio-Economic Survey	2005	7,425	5,726	51.5	58.3
Vietnam	Household Living Standard Survey	2004	9,188	6,938	21.4	26.4
Zambia	Living Conditions Monitoring Survey	2002	4,166	2,090	61.9	59.4

Source: Authors' database

Table 2: Projected growth rates and total growth between 2010 and 2050 in the baseline scenarios (in pct)

	Population	Capital	Labour	GDP	Implied TFP productivity growth
Developed	0.2	2.4	0.2	2.3	1.3
East Asia	0.2	5.6	0.3	4.7	1.9
Europe & Central Asia	-0.1	2.1	0.3	1.8	0.7
Latin America	0.7	1.8	0.7	1.6	0.4
MENA	1.0	2.9	1.1	2.8	0.6
South Asia	0.9	4.5	0.9	4.5	2.2
Sub-Sahara Africa	2.0	2.0	1.6	1.7	0.2
Total	0.7	2.8	0.6	2.6	—

Sources: US Census Bureau, Poncet (2006)

Table 3: Overview of global output changes

	Baseline		Higher agric growth		Higher agric growth developing	
	World	Developing	World	Developing	World	Developing
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

Source: Authors' calculations

Table 4: Overview of global price changes (in pct, deflated by global CPI)

	Baseline		**Higher agric growth**		**Higher agric growth developing**	
	World	Developing	World	Developing	World	Developing
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

Source: Authors' calculations

Table 5: Regional price impacts of the protection scenario (relative to baseline)

	East Asia	Europe & Central Asia	Latin America	South Asia	Sub-Saharan Africa
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

Source: Authors' calculations

Table 6: Country level poverty impacts (relative to the baseline)

	Higher agric growth developing	**Higher agric growth developing**	**Protection developing countries**
Albania	1.0	0.4	0.0
Armenia	-2.0	-1.8	0.3
Bangladesh	-16.0	-14.4	9.3
Cote d'Ivoire	-3.8	-4.7	0.6
Guatemala	-7.0	-6.4	0.7
Cambodia	-3.0	-3.8	2.6
Mongolia	-3.9	-3.6	0.2
Malawi	-12.1	-11.7	0.4
Nepal	-4.4	-4.4	-0.8
Nigeria	2.6	0.7	-0.1
Niger	-2.3	-2.6	0.7
Pakistan	-13.8	-12.3	22.4
Panama	-2.4	-2.3	0.1
Peru	-2.0	-2.0	0.2
Rwanda	-2.4	-2.1	0.1
Tajikistan	-7.6	-7.0	0.7
Timor-Leste	-10.8	-9.7	6.2
Uganda	-7.0	-7.1	0.1
Vietnam	-4.8	-6.2	2.8
Zambia	-6.7	-6.6	0.8
Average	-5.4	-5.4	2.4

Source: Authors' calculations

Table 7: Decomposition of the sources of poverty change

		Raw agriculture		Processed food		Fishing and forestry		Other		Wage	Total
		Consum-ption	Produc-tion	Consumption	Production	Consump-tion	Produc-tion	Consump-tion	Produc-tion		
Higher ag productivity	World	-5.6	1.5	-0.5	0.2	0.3	-0.3	3.0	-1.1	-3.0	-5.4
	SSA	-6.2	1.2	0.1	0.0	0.5	-0.1	3.8	-1.2	-1.9	-4.0
	LAC	-3.9	1.3	-0.8	0.2	0.0	0.0	0.2	0.0	-0.8	-3.8
	SAR+EAP	-5.3	1.7	-0.4	0.1	0.4	-0.6	3.6	-1.8	-5.2	-7.6
	ECA	-3.1	1.2	-1.3	0.5	0.0	0.0	1.1	0.0	-1.6	-3.2
Higher ag productivity developing	World	-4.5	0.5	-0.3	0.1	0.3	-0.2	2.3	-0.9	-2.6	-5.4
	SSA	-5.0	0.1	0.1	0.0	0.4	-0.1	2.8	-0.9	-1.6	-4.2
	LAC	-3.2	0.7	-0.6	0.1	0.0	0.0	0.2	-0.1	-0.6	-3.6
	SAR+EAP	-4.3	0.6	-0.2	0.1	0.3	-0.6	2.8	-1.5	-4.4	-7.3
	ECA	-2.6	0.8	-0.9	0.4	0.0	0.0	0.7	0.0	-1.3	-3.0
Protection by developing	World	2.4	-2.1	-0.3	-0.1	-0.2	0.3	-1.3	1.2	2.5	2.4
	SSA	0.9	-0.4	-0.1	0.0	-0.1	0.0	-0.5	0.2	0.2	0.3
	LAC	0.4	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4
	SAR+EAP	5.5	-5.6	-0.8	-0.3	-0.5	0.9	-3.1	3.1	6.8	6.1
	ECA	0.2	-0.1	0.1	0.0	0.0	0.0	-0.1	0.0	0.2	0.3

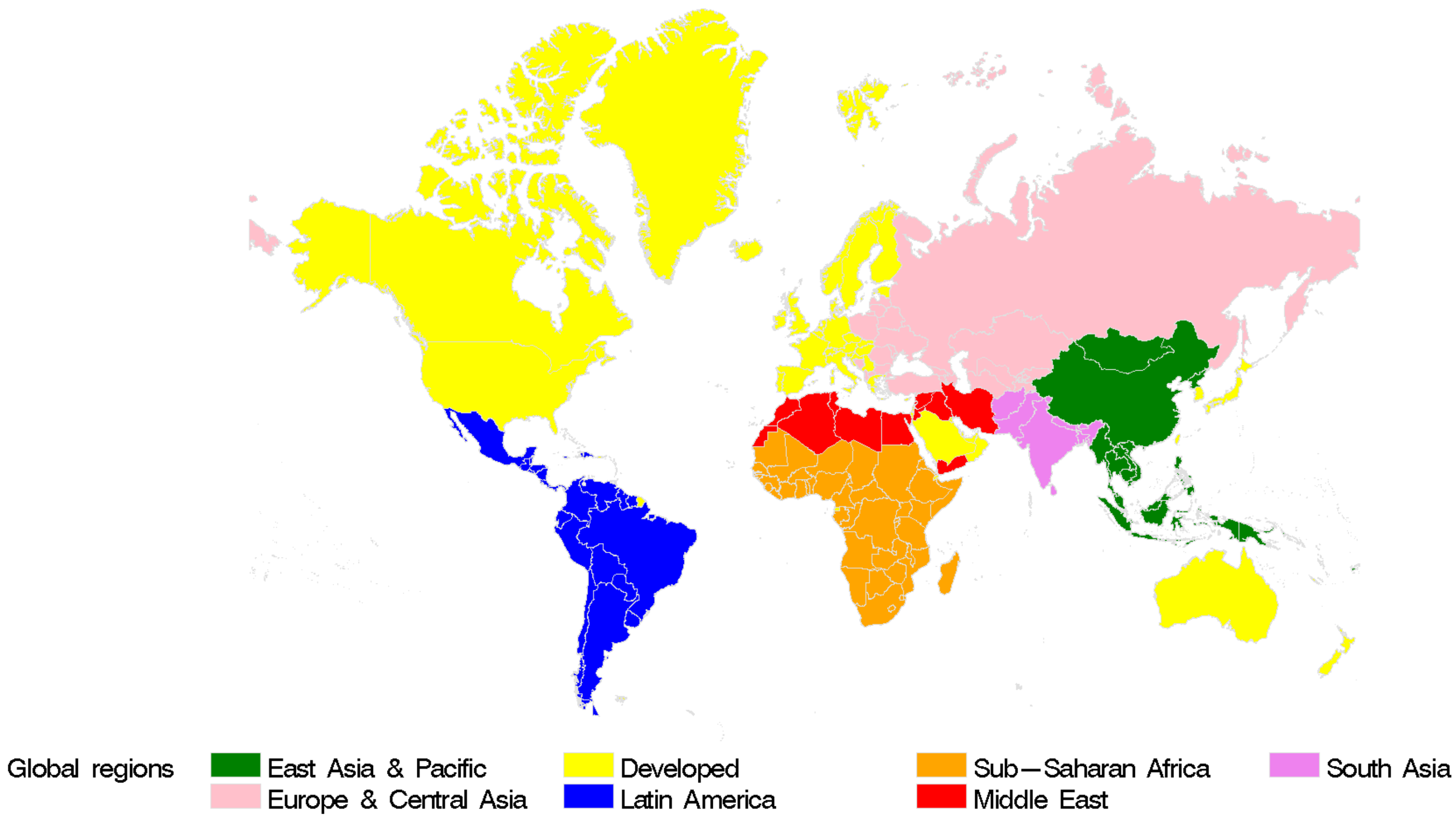
Sources: Authors' calculations

Table 8: Decomposition of the poverty impacts of improved agricultural productivity in rice and wheat

	Rice			Wheat		
	Agriculture and food		Other impacts	Agriculture and food		Other impacts
Adoption rate	Consumers	Producers		Consumers	Producers	
1.0	-0.46	0.11	0.01	-0.28	0.11	-0.02
0.8	-0.46	0.12	0.01	-0.28	0.11	-0.02
0.6	-0.46	0.14	0.01	-0.28	0.11	-0.02
0.4	-0.46	0.18	0.01	-0.28	0.12	-0.02
0.2	-0.46	0.23	0.01	-0.28	0.12	-0.02
0.0	-0.46	0.34	0.01	-0.28	0.13	-0.02

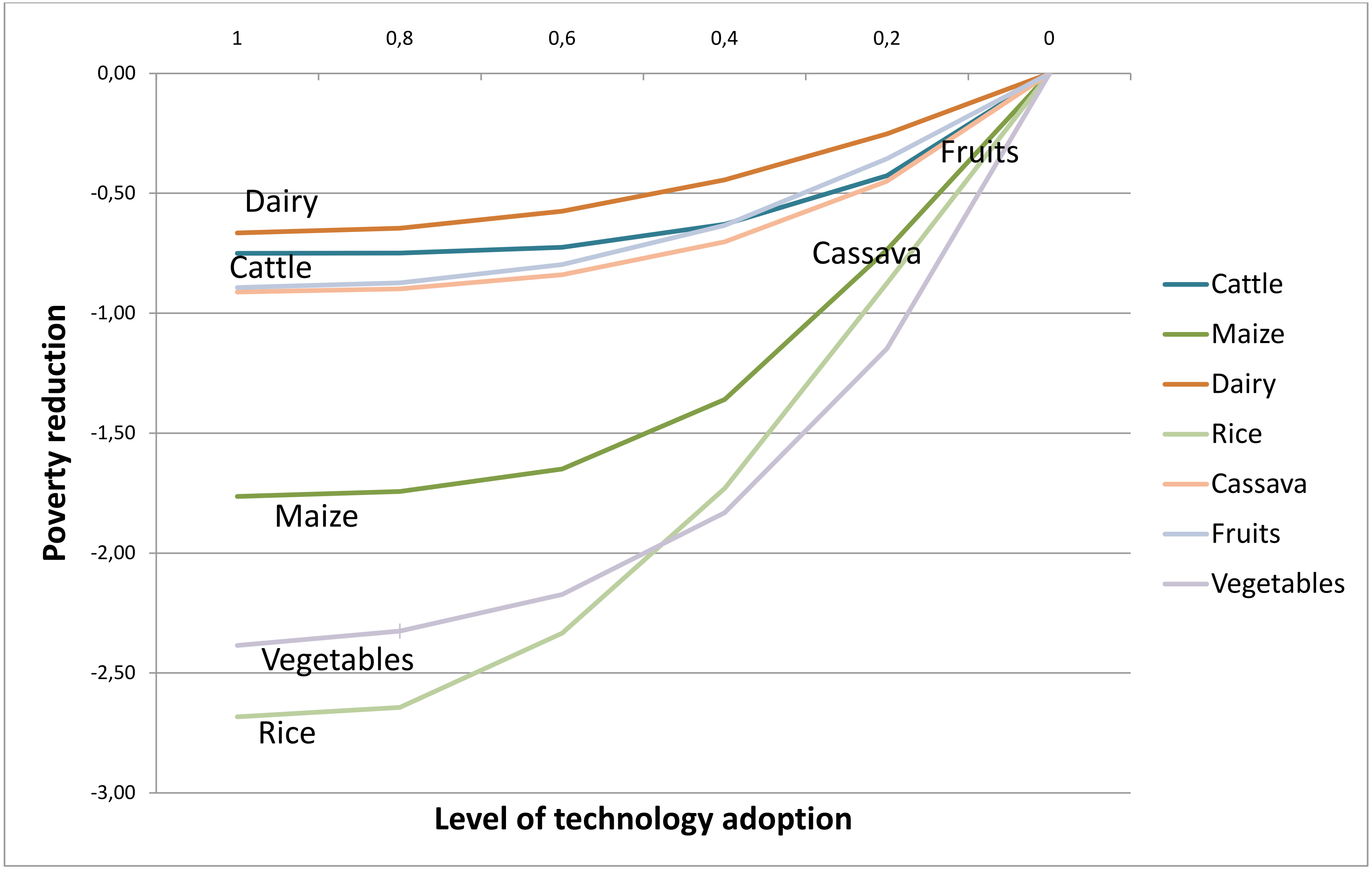
Source: Authors' calculations

Figure 1: Regions defined and used in this work



Source: The World Bank

Figure 2: Relationship between agricultural innovation and poverty reduction for a different level of innovation adoption



Source: Authors' calculations