Poverty Vulnerability and Trade Policy: Are the Likely Impacts Discernable?

Ernesto Valenzuela and Thomas W. Hertel

Valenzuela is an ET-Consultant with The World Bank, Washington, D.C.

Hertel is Distinguished Professor, Department of Agricultural Economics, and Research Director, Center for Global Trade Analysis, Purdue University.

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Abstract

Trade policy reform prospects have generated debate about the impacts on poverty. Some critics assert that price changes induced by trade reform are minimal and may not be distinguishable from price fluctuations induced by other shocks to the global economy. This paper addresses this issue by developing an approach to assess whether poverty changes induced by trade reform can be statistically discernable, based on a comparison in the grains sector. Fluctuations in grains markets are implemented by incorporating stochastic simulations into a CGE model of the global economy. The resulting price distributions are inputted to a micro-simulation based on national household surveys. The conclusions are based on the comparison of the resulting poverty distributions from the weather-induced variability only, versus the combined effect of the latter and trade reform. Results indicate that, in this conservative approach of evaluating only the global grains markets, the short-run impacts on poverty of trade liberalization can not be distinguished from market volatility in some countries.

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*Contact author:
Ernesto Valenzuela
Development Research Group
The World Bank
Mailstop MC3-303
1818 H Street NW
Washington DC 20433 USA
Phone +1 202 473 8095
evalenzuela1@worldbank.org

1. Introduction

Rural poor represent 75 percent of the world´s poverty (World Bank, 2004). They mostly depend on agriculture for their livelihoods, which in turn makes them particularly susceptible to agricultural commodity price volatility. These fluctuations are often quite large due to a combination of factors, including: inelastic demand and supply, perishability, high transport costs, and exposure to random climatic shocks. These fluctuations in agricultural prices not only affect household´s incomes, but also production decisions, by creating uncertainty about input and harvest prices (Gabre-Madhin et al., 2003). Both effects exacerbate the vulnerability of the poorest households in developing countries, for whom staple food products may represent as much as 60 percent of expenditures.

What are the consequences of ignoring the effect of price variability on poverty? The answer to this question is particularly relevant for low-income countries in the context of ongoing global attempts to reform trade. Household income and consumption patterns are affected by changing relative domestic prices resulting from trade liberalization (Ruffin and Jones, 1977; Anderson, 2005). Consequently, current trade policy reform prospects have generated an intense debate about the impacts on poverty. Within this debate, some critics assert that price changes induced by trade reforms are minimal in comparison with other shocks to the global economy. Therefore, they conclude it is likely that poor households will not perceive a tangible difference in their welfare. In particular, Dani Rodrik, in a critique on Cline´s (2004) book on trade policy and poverty, makes the point that the impact of agricultural domestic support programs in developed economies on world prices are likely to be dwarfed by the inherent volatility of agricultural markets. He bases his argument on the comparison of world price outcomes in studies of global trade liberalization with the observed standard deviation of year-to-year price variability in primary commodity markets. His conclusion from this simple comparison is that the latter are large, relative to the former. While his brief remarks were meant to stimulate debate at the Center for Global Development, they do stimulate interest in a more formal empirical analysis about the relative poverty impacts of price volatility versus trade policy induced changes.

The literature is scarce on the poverty impacts of price variability within the context of trade reform. The effect of openness on income distribution has been extensively studied, generally as an issue of factor reallocation from import competing to export sectors, or through the effect of openness to trade on wage inequality (Robbins, 1996; Lunati and O´Connor, 1999). More recently, Bourguignon et al. (2004) develop a framework to assess household income volatility in less-developed countries with respect to export price variability. Their results show that policies that are similar in terms of expected average income can have quite different effects in terms of income variances. While their framework serves the purpose of identifying the need to assess the distribution of risk in addition to the usual assessment of the average income, their use of an archetypal economy and their artificial generation of export price shocks precludes definitive statements about the relative impacts of trade policy and price variability on poverty.

The purpose of this study is to evaluate whether trade policy-induced poverty changes are statistically discernable from the inherent effects of agricultural price fluctuations. We focus particularly on staple grains as they represent an important share of the budget for the poorest households. We analyze fifteen developing countries in South Asia, Latin America and Sub-Saharan Africa. We model volatility in staple grains production by sampling from a distribution of productivity shocks derived from time series econometrics. This supply-side volatility is implemented in a Computable General equilibrium (CGE) framework, the agricultural-specific GTAP-AGR model (Keeney and Hertel, 2005). The general equilibrium approach permits us to capture the implications of changes in national commodity and factor prices, resulting from alterations in global trade policies as well as uncertainty in world grain yields, while retaining economy-wide consistency. Following Hertel et al. (2004), the distributions of factor and commodity prices are fed into a series of micro-simulation models which capture the impact on household income– through the changes in relative commodity and factor prices. The micro-simulation model determines the change in household utility. If the latter rises above the poverty level of utility, as defined initially for that country, then they are deemed to be no longer poor. On the other hand, if the commodity price increase pushes them below the poverty level of utility, they are added to the poverty headcount. The resulting ex ante poverty distribution reflecting vulnerability to agricultural prices variability is compared to trade reform effects.

By implementing the stochastic structure in conjunction with Hertel et al.'s framework, this work contributes to economic analysis in devising a relevant yardstick with which short-run poverty consequences can be measured in their potential of being discernable from the inherent volatility induced by commodity markets. Additionally, this paper seeks to shed light on the issue of whether trade policy reform and openness offer the right path to poverty reduction, or whether efforts should be redirected to stabilization food price schemes to secure the well-being of the lowest-income people.

The remainder of this article is organized as follows. The next section explains the notion of poverty vulnerability. Third the methodology used is described, starting with the CGE model and data aggregation, survey data, the stochastic framework in the CGE model, and the micro-simulation system. The following section presents the ex ante calculated distribution of poverty changes, welfare results of the trade liberalization, and the evaluation of significant poverty impacts of global trade reform. Finally, the last section draws conclusions and policy implications.

2. Background on Measuring Vulnerability to Poverty

Much of the policy debate over poverty is inextricably entangled with vulnerability. However, there is no consensus about how to define and measure vulnerability (Kamanou and Morduch, 2002). In a general context, vulnerability is related to lack of educational opportunities, mortality, poor nutrition and health care, and the occurrence of climatic, social, and political distress.

Dercon (2001) suggests that for operational use the notion of vulnerability should be tied to a benchmark, which in turn could facilitate its measurement. He argues that in the context of poverty policy, vulnerability to poverty is the appropriate concept. He clarifies this definition explaining that well-being and poverty are the ex post outcome of a complex decision process of households over income and expenditures, faced with risk; and that vulnerability to poverty is the ex ante situation, i.e. before one has knowledge of the actual shocks that will occur. Vulnerability is determined by the options available to households to make a living, the risks they face, and their ability to cope with these risks.

Measures of vulnerability to poverty could be derived in its various dimensions (e.g., income, or consumption of a bundle of goods). One possibility is to tie the measurement of vulnerability to a welfare framework, in which the outcome of potentially occurring negative situations is weighed against a socially defined minimum level (see Ligon and Schechter (2002) for an instructive overview). An operational option is to generate an outcome-based measure of vulnerability, in which distributions of prices and income are generated resulting in changes in poverty which could be labeled as an ex ante distribution of poverty.

Ideally, one would wish to track individual household outcomes in each possible situation, and based on a pre-determined minimum level of well-being, establish which households are permanently poor, those becoming permanently poor in the future, and those who will be temporarily (seasonally) poor. This could lead to the definition of low and high vulnerability groups, which could find a great use in policy work comparing vulnerability of different regions or social groups.

The problem however, is that even with the availability of detailed household surveys, information requirements are excessive and no straightforward measurement of hypothetical situations is possible. Most of the work on this topic infers the distribution of possible outcome shocks from the error process in cross-section regression models (Pritchett, et al., 2000) or from panel data in which inter-temporal measures are not too distant (Dercon and Krishnan, 2000), which implies strong assumptions about how shocks evolve over time and space. Dercon (2001) argues that uncertain assumptions about statistical error processes could be replaced by explicitly modeling households' ability to cope with shocks. By using survey data on shocks faced, combined with historical sources on large or common shocks such as climatic variations, price shocks, etc, it could be possible to derive measures of vulnerability allowing for more realistic models which involve risk and differential household's risk-coping ability. Additionally, the inclusion of risk modeling and the availability of two or more period records in surveys could aid in the generation of transition matrices depicting movement of households in and out of poverty.

The approach taken in this study is more modest, as households' ability to cope with risk is not included in the modeling and there are no inter-temporal measures in the household analysis. An ex ante poverty distribution reflecting vulnerability to staple grain prices variability is produced by implementing prices and income distributions in the household model. These price and income distributions are obtained through stochastic simulations based on historically-derived production variability.[1] Given that our focus is on staple grains markets, only trade reform effects due to grains sector is considered. These trade reform effects are combined with the productivity shocks to produce a second stochastic process. The analysis is limited to the comparison of the resulting *inherent* (i.e., from the historical shocks to production only) poverty distribution with the resulting trade reform (shocks to production and trade reforms).

3. Methodology

The macro-micro modeling approach used in this study is outlined in figure 1. Starting with the upper-left corner, information contained in households surveys previously processed by Ivanic (2004) are reconciled with the GTAP database to ensure consistency.

[1] The rationale is that one recurrent bad situation for poor households, and out of their control, is food price fluctuations induced by unpredictable weather fluctuation.

The reconciled surveys are used in conjunction with World Bank country's poverty headcount estimates as inputs to the micro simulation framework. The upper-right section of the diagram shows the sequence of how volatility in production and trade policies are modeled within the CGE model. Uncertainty in grains supplies is modeled as a series of stochastic productivity shocks resulting into a distribution of consumer and factor price changes. Trade policy reform in grains is modeled in combination with the stochastic shocks in productivity producing a different distribution of consumer and factor price changes. The resulting CGE-generated distributions of prices and income are inputted into the micro-simulation model (about the center of the diagram), representing the pool from where a unique vector of prices is sampled to predict a distribution of regional poverty headcount changes. Finally, shown at about the bottom of the illustration, the assessment of the significant differences between trade policy effects and the inherent volatility in grains markets is based on a two-sample t-test of the ex ante poverty distribution attributed to variability in production with the ex ante poverty distribution of the combination of trade policy and variability in production.

The following subsections provide details on the CGE model and global database used, household surveys, stochastic modeling, and the micro-simulation.

The CGE model and Data Aggregation

An analysis of poverty needs to take specifically into account agricultural commodity markets. Not only is a large share of the poor in developing countries employed in farming, but also the poor spend most of their income on food. To compound this situation, agricultural and food trade is more affected in comparison with other sectors by the presence of high tariffs (see table 1), and agricultural production in developed economies receives a large amount of transfers from consumers and tax payers.[2] For these reasons, this study employs the GTAP-AGR model of Keeney and Hertel, (2005)

[2] The OECD reports 227 US billion in producer support to agricultural producers in 2001.

which is intended to account for specifics of agricultural markets (see appendix 1 for summary details of the CGE model). Several World Bank studies on trade policy issues utilize this framework to address the intricacies of agricultural markets (Hertel and Winters (2006) on poverty issues; Anderson and Martin (2006) in WTO negotiations assessment; Anderson and Valenzuela (2006) in cotton markets and trade policies).

Given the nature of the stochastic production process, short-run assumptions on the factor markets are implemented. Land, capital and self-employed labor are immobile, and the returns to these factors are combined into sectoral profits, which correspond to the agricultural and non-agricultural profits reported in the household surveys. Wage and salaried workers are assumed to be mobile within agricultural and non-agricultural sectors, and the region-specific supply labor elasticity of the AGR model determines the limited mobility of labor between agricultural and non-agricultural sectors.[3] In addition, one relevant characteristic is the modification of the model to accommodate a tax replacement of lost revenue from the absence of tariff collection, in the form of a non-distorting uniform *ad valorem* tax on primary factor endowments making each scenario fiscally neutral.

The GTAP database release 6 is utilized, which depicts the global economy in 2001. According to this database, the average import tariff in high–income countries for agriculture was 20.7 percent, 13.1 for processed food, and 2.0 for manufacturing. While in developing countries, for primary agriculture was 16.5 percent, 18.7 for processed food, and 9.4 for manufactures (see table 1 for regional details). In spite of the fact, that averages obscure large variations across countries and commodities, these estimates point out to a disproportionate distortion in agricultural trade with respect to other sectors.

The level of aggregation is defined at 27 regions and 9 sectors. The regional

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[3] These parameters for developed economies are based on OECD estimates; however, given the lack of information for developing countries, the GTAP-AGR imposes the parameter of Mexico for all other developing regions.

aggregation describes major trading blocs, and singles out 15 developing countries for which detailed household survey information is available. The sectoral aggregation is aimed to provide some detail in agricultural production while avoiding deviating too much from the broad six sectoral aggregation of the demand system (see tables 2 and 3).

Household Survey Data

Fifteen developing countries are selected for this poverty analysis based on availability of detailed earnings information in the household surveys and country coverage in the global database. Information on earnings of these surveys was processed by Ivanic (2004). This sample contains: six Latin-American, four Sub-Saharan Africans, and five South Asian countries, which provides a fairly general coverage of global poverty. Table 4 lists the 15 focus countries and provides economic indicators. In this sample, the majority of the poor are found in South Asia with a total number of poor people of 114 million, which represents 11 percent of this sample population. The lowest GDP per capita at purchasing power parity prices is found in the African countries, which on average features values 4 times smaller than in South Asian countries, and almost 8 times smaller than in Latin-America. The third column of table 4 provides agricultural value added as a percentage of GDP, which indicates the reliance of these economies on agricultural production. This information shows that most Asian and African countries are heavily dependent on agriculture, while Latin American countries are more dependent on industry value added, and increasingly more on services (World Bank, 2004).

Following Ivanic (2004), the available survey data were reconciled with the GTAP data to ensure consistency. The surveys data on GDP were increased to match the GTAP data (based on national accounts). The surveys were modified by scaling the reported household capital income to match the level of the GTAP data. The GTAP database was adjusted as well, by altering the endowments of unskilled and skilled labor based on the survey information. Given that the focus of this work is to assess poverty vulnerability in the presence of volatile production, and that this process is conceived as a short-run phenomenon (defined here as one year horizon), returns to self-employed labor and capital are also distinguished.[4]

Modeling Global Trade Reform

This study considers a scenario of full trade liberalization, which involves the complete removal of tariffs and import quotas on all commodities, and the elimination of agricultural subsidies (exports and production). In order to keep consistency at a sectoral level with the variability in staple grain production, the focus is specifically on trade reform in staple grains — therefore, after implementing trade reform in all goods the effect due to reform in staple grains is isolated. Although a full liberalization scenario is remotely politically feasible, its modeling is useful in quantifying the maximum extent of trade reform, and thus providing a useful benchmark for assessing the relative magnitude of poverty impacts with respect to the inherent volatility in grain prices.

In addition to the full liberalization scheme, two options of global trade reform are evaluated with respect to the inherent volatility in markets. The first is a 50 percent reduction in tariffs, and subsidies to production and exports. The second corresponds to the tiered formula proposal of the WTO's Doha Development Agenda (DDA) negotiations. This proposal implements deeper cuts in higher tariffs and preferential treatment to developing countries, complete elimination of export subsidies, and a reduction in domestic support 28 percent in United States, 16 percent in the EU, and 10 percent in Australia. (See Anderson and Martin (2006b) for details of the DDA tiered formula proposal).

Stochastic Modeling: Characterizing Volatility in Grains Markets

[4] To reflect a short-run production process, the capital endowment in the GTAP database is modified as to explicitly account for self-employed labor, by exploiting the property of estimation of imputed labor in the surveys data (Ivanic, 2004).

The modeling of uncertainty in world food markets was illustrated by Tyers and Anderson (1992), and Vanzetti (1998), by sampling from a distribution of supply shocks. Vanzetti characterizes variability in wheat production for the period 1960 and 1994 by separating increasing technical change from weather induced yield variability. Hertel, Keeney and Valenzuela (2004) propose the use of region specific time series modeling to remove systematic changes in wheat output, leaving prediction errors that represent yield fluctuations.

We utilize autoregressive integrated moving average (ARIMA) models to characterize systematic changes in staple grains production, and use the residuals of these estimations to define our distributions of productivity shocks. We use staple grains production data from the Food and Agriculture Organization for the period 1966 to 1995 (FAOSTAT, 2005)[5]. The determination of supply variability does not focus particularly on the countries with household information, but instead we calculate a regional shock, letting focus countries of the poverty analysis inherent the parameters from the parent region[6]. The model selection is guided first on the determination of stationarity (Dickey-Fuller test), and the definition of the autoregressive and moving average processes based on the sample autocorrelations, and partial autocorrelations. Final model selection for each production series is determined on the significance of the AR and MA components and the Akaike Information Criteria (AIC) for alternative models comparison. The third

5 Staple grains mapping from FAO Definition to GTAP Commodities:

GTAP database	FAO Cereals, Total (No. 1717)
Wheat	Wheat
Paddy rice	Rice, Paddy
Cereal grains	Barley, Maize, Pop Corn, Rye, Oats, Millet, Sorghum, Buckwheat, Quinoa, Fonio, Triticale, Canary seed, Mixed grain, cereals nes.

6 This assumption simplifies considerably the solving stage of the problem, as it is not necessary to explicitly calculate output covariances by country and thus the standard features of sensitivity analysis in the RunGTAP software are used (see Pearson and Arndt (2000) for implementation of the Gaussian procedure in GEMPACK).

column in table 5 describes the model selection for each series. The normalized standard deviation of the residuals from the estimated time series models are shown in the second column of table 5. These residuals representing variability in production after eliminating the deterministic trend show the greatest variation in Oceania, Middle East North Africa, North America, and Former USSR.

The next step is to translate grains production variability into a form useful for stochastic simulations of the CGE model. Following the approach of Arndt (1996) and Pearson and Arndt (2000), we characterize productivity variation with a symmetric, triangular distribution as the basis for a stochastic simulation of the CGE model. The endpoints of the distribution are determined by the formula Mean ± $\sqrt{6V}$.

Formally, if the general equilibrium model is defined in a general form by:

$$G\ (k, e) = 0 \qquad (1)$$

where k represents a vector of endogenous variables, and e a vector of exogenous variables. A solution to equation (2) in the form of $k^r(e)$ produces a vector of results of interest $k^r(e) \equiv H(e)$. In our framework, e is the vector of grains productivity shocks which yields distribution of factor and commodity prices (random endogenous variables). The mean and variance results for the endogenous variables take the forms:

$$E[H(e)] = \int_{\Omega} H(e)g(e)de \qquad (2)$$

$$E\left[(H(e) - E[H(e)])^2\right] = \int_{\Omega} (H(e) - E[H(e)])^2 g(e)de \qquad (3)$$

where *g(e)* represents the multivariate density function, and Ω is the region of integration.

Arndt(1996) states that treating a general equilibrium simulation as a problem of numerical integration enable us to deal simultaneously with the solution for the general equilibrium and the randomness of exogenous variables. In this process a new equilibrium is found after each random draw from the calculated regional productivity shocks distributions. As an alternative to Monte Carlo approaches, we employ the Gaussian Quadrature (GQ) numerical integration technique developed by Stroud (1957) and Haber (1970), and implemented to policy analysis by Devuyst (1993), and DeVuyst and Preckel (1997). They show that an approximating discrete distribution can be obtained based on known lower-order moments of the model parameters. In turn, selectively solving the model based on the moments of this approximate distribution generates results consistent with the Monte Carlo approach, with far fewer simulations required. Implementation of the GQ procedure in the GTAP model is documented in Pearson and Arndt (2000).

Poverty Analysis

The distribution of factor and commodity prices -- random endogenous variables, generated by the CGE model, are imputed into a micro-simulation model, from which changes in consumption and income levels determine a distribution of utility changes. In particular, we follow Hertel et al.'s (2004) framework by adopting an implicitly directly additive demand system (AIDADS of Rimmer and Powell 1992a, 1992b, 1996) to obtain a utility function for each country (Cranfield et al.,2004). The results of trade liberalization and volatility in production will alter the wages associated with each endowment, the price of capital goods and transfers. The resulting new vector of commodity prices and income levels are used to determine expenditure on each good, and hence individual demands. Thus, defining a change in each household's utility (see appendix 2 for details on the micro-simulation framework). Based on the distributions of utility post-stochastic production, and the combination of the latter with trade liberalization, two separate distributions of change in poverty headcount can be calculated. The assessment of the significant differences between these two distributions is based on a two-sample t-test.

4. Results

This section first presents the regional ex ante distribution of poverty changes as a result of the variability in staple grain supplies. Next, the results of the global trade reform (full liberalization) scenario are presented as welfare changes in the representative household of the CGE model, and as predicted poverty impacts resulting from the micro-simulation model. Afterwards, the relative magnitudes of poverty changes of the full liberalization and partial reform with respect to the inherent price volatility distributions are assessed.

Staple Grains Price-Induced Distribution of Poverty

Table 6 shows the distribution of poverty changes induced by the natural variability in grains markets. The first column depicts the mean of the changes in poverty headcount (in percentage terms), showing that staple-grain price volatility induces a positive mean in the poverty changes distribution in all cases, as expected given the convexity of the income distribution[7] — there is a greater movement of people into poverty after a decrease in income, than out of poverty after an increase in income.

The second column gives the standard deviation of the poverty distribution, which is interpreted as a measure of vulnerability to poverty — households are judged to be more vulnerable if standard deviations of poverty changes are higher. One of the limitations of using the standard deviation as a measure of vulnerability, is that downside risk is weighed the same as upside risk — yet poor people are concerned primarily with downward fluctuations. An additional concern with the framework is that it imposes strong homogeneity assumptions, namely that all households in a region receive draws from the same distribution of staple grains supply shocks. However, the advantage of focusing the analysis on the standard deviation is that this represents a simple measure of

[7] More formally, the Lorenz curve is the graphical representation of income distribution, with percentage of households in the x-axis, and percentage of their corresponding income in the y-axis. This curve is strictly increasing and convex.

vulnerability that is comparable across regions. The concept is easy to grasp drawing on the association of vulnerability with variability, and it avoids the need for additional assumptions on structures and parameters (e.g. penalty functions).

The standard deviation results show that low-income households in Latin-America seem to be least affected by grain price volatility, while this measure of vulnerability is generally higher in South East Asia and Sub-Saharan Africa, with exceptions in Thailand and Zambia. What determines this regional pattern of vulnerability to poverty induced by grains markets? To answer this question, first it is relevant to compare the volatility of grains supplies in these regions. The estimates shown in the second column of table 5 for Latin-America, South Asia, and Sub Sahara Africa are 5.75, 5.66, and 7.65 respectively. This variability by itself cannot account for the difference in regional vulnerability. The answer to the above question could be found in the dependence of these economies on primary agricultural income as shown in the third column of table 4, Latin-America as a region is less dependent on primary agriculture income as a proportion of its GDP (in general less than 10 percent), while it represents close to a quarter of value added in South Asia, and one third in some African countries. The low vulnerability to staple grains prices fluctuation in Thailand is related to their low reliance of their economies on payments to agricultural factors (9 percent). In the case of Zambia, although its economy relies to some extent in agriculture income (22 percent), the poverty headcount as a proportion of total population, which does not depend on agricultural income, represents more than 50 percent (Valenzuela et al., 2003).

The general conclusion of this analysis is that in countries showing great poverty vulnerability to grain output variability as defined by their income reliance on agricultural production— e.g., Bangladesh, Indonesia, Philippines, in South Asia; and Mozambique and Uganda in Sub-Saharan Africa, in order to be discernable from market price fluctuations, poverty impacts of trade policy will have to be large.

Results of Global Trade Reform

Welfare Results

Table 7 presents the welfare impact, reported as the Hicksian Equivalent Variation (EV) measure, for the representative household in each economy. The total EV (first column) shows for South Asian countries a general increase in welfare, with the exception of Philippines. However, there is not a clear *win-win* situation in Latin-America and Sub-Sahara Africa, and the analysis must be done on an individual country basis.

The analysis is facilitated by decomposing the welfare changes with respect to the exogenous policy shocks (Harrison et. al., 1999). The second and third column in table 7 show the changes due to own and foreign policy reform, and columns 4, 5, and 6, provide the sectoral contribution (*grains*, *other agriculture & food*, and *other merchandise*, respectively) to the change in real income.

The general pattern in this sample of developing countries is that in the short-term they lose from the own policy reform due to adverse terms of trade effects, but the gains due to a high market access in foreign countries more than compensate for the losses resulting in a net gain. One relevant exception to this pattern is Mexico, which is expected to experience erosion in its preferential trade position with Canada, and United States (as part of the NAFTA agreement) in the case of multilateral trade reform. Most of the changes in real income are induced by non-agricultural liberalization, and the countries' net gain or loss seems to be determined by the size of this sectoral contribution.[8]

Analyzing the countries that experience a welfare decrease, we find that Philippines shows most of the changes in real income in the *grains* sector. Colombia experiences large losses in *other merchandise* sector, medium losses in *staple grains*

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[8] The 6.0 release of the GTAP database, with a 2001 base year, still includes export quotas on textiles and apparel under the Agreement on Textiles and Clothing, which will tend to inflate the gains in comparison with a more current base year.

markets, and some gains in *other agricultural & food products*. The net welfare loss situation in Colombia is determined by disfavorable terms of trade effects in the *other merchandise* liberalization, as a result of losing its relative preferential position enacted by the Andean Trade Preferential Act (ATPA) agreement with United States, and the lack of full implementation of the Agreement on Textiles and Clothing industry (ATC) in the 2001 base year. Venezuela's losses in welfare are a result of own reform as well as foreign policies. The sectoral composition shows that Venezuela will experience a decrease in welfare across all sectors. One explanation could be found in the fact that Venezuela's economy relies heavily in oil exports (the oil sector accounts roughly a quarter of GDP and 80 percent of export income, (EconSouth, 2002)), for which there is no tariff structure in place for its commerce, and thus the trade reform does not bring any substantial change in income in this industry relative to other sectors in the economy. In Sub-Saharan Africa, the decrease in Mozambique's real income produced by own policy reform outweighs the gains from foreign policy reforms. The sectoral decomposition shows that there is no welfare change derived from non-agricultural reforms, and most of the losses come from the *other agriculture & food* sectors. In Uganda, losses in real income result from own policy as well as foreign policy reforms. All three aggregated sectors show a decrease in welfare.

Poverty Results

The impacts on poverty of global trade reform are shown in table 8 as the percentage change in poverty headcount (first column), and the change in poverty headcount in thousands (third column). One can observe that the short-run effects of trade liberalization do not impose a consistent decrease (or increase) in poverty across the regions. Importantly, there are some countries showing an increase in poverty for which previously it was reported an increase in welfare based on the analysis of the representative household of the CGE model (i.e., Indonesia, Brazil, Peru, and Zambia). Additionally the reverse pattern is also found, where countries showing a decrease in welfare for the representative household experience a decrease in the poverty rate (i.e., Philippines, Colombia, Venezuela, and Mozambique). This finding lends support to the importance of assessing policy impacts along the income distribution, and it highlights the need to depart from the representative household evaluation.

In order to keep the comparison of the poverty impacts of trade policy reform consistent at a sectoral level with the modeled ex ante distribution of poverty induced by variability in grains markets, the poverty effects of reform in grain markets are isolated. These effects are shown in the second column of table 8 as a percentage change in poverty headcount, in the thousands of people moving in/out of poverty in column 4, and as percentage of trade reform in all sectors in column 5.

With the exceptions of the Andean countries, trade reform in staple grains leads to an increase in short-run poverty across all regions. The salient characteristic in the grains markets of the Andean countries is that after full liberalization these economies became net importers, contracting their production, and benefiting from reallocation of resources to other agriculture sectors.[9]

Based on the relative magnitude of the poverty impacts of grain reform with respect to liberalization in all goods, one could rank the sample countries in tiers of high, medium, and low impact. Indonesia, Philippines, and Uganda show a high relative poverty impact. Thailand, Mexico, and Mozambique show a medium impact, and countries like Vietnam, Brazil, and Malawi exhibit a small relative poverty impact.

Comparison of Trade Reform with Supply Variability Induced Poverty Changes

The grain reform induced poverty impacts are evaluated against the market volatility induced effects. In doing this *single* sector comparison one is taking a conservative

[9] Additional characteristics about Andean grains markets, not captured in this modeling, are: The existence of price bands mechanisms to regulate its trade and effectively support high domestic prices; and the application of non-tariff barriers related to phyto-sanitary measures.

approach. Although weather-induced variability in grain supplies is a source of volatility affecting the poor, there are other large economic shocks triggering the decline in welfare of the poor – e.g., shocks to labor demand due to business cycle, volatile export demand.

Figure 2 shows the plotting of the distributions of poverty changes in Mozambique, Uganda, and Indonesia. These countries are chosen to illustrate cases where the effects of trade reform may not be discernable from market variability (Mozambique), somewhat recognizable (Uganda), and where poor households are affected in a larger degree (Indonesia).

Table 9 shows the results of the formal statistical comparison of the two distributions of poverty changes. The first column shows the calculated t-statistics, and to aid the visualization, significant differences are represented by non-shaded areas. The broad findings are that short-run poverty changes resulting from a full trade reform (in staple grains) are large enough to be differentiated in 10 out of the 15 countries in this study. The recognizable (i.e. distinguishable *from the inherent market volatility*) poverty decrease in the Andean economies show that trade reform is a valid means to improve the economic conditions of the lowest households in these economies. In the same vein, the results show that low-income households in Bangladesh, Indonesia, Vietnam, Brazil, Chile, Mexico, and Uganda are markedly affected by trade reform in grains markets. This finding is particularly informative when assessed in combination with a medium term horizon of trade reform impact. Ivanic (2006, Table 14.6) using a static framework, predicts medium-term poverty reduction effects of global trade reform in all goods in Indonesia, Vietnam, Brazil, and Chile. The policy implication for these countries is that it is necessary to devise some sort of safety net mechanism oriented to help lowest income households weather the adjustment to trade reform.

The findings of discernable increase in poverty in the short-run, and Ivanic's medium-term predictions of increase in poverty in some countries (Bangladesh, Mexico, and Uganda), suggest that under the objective of poverty reduction, trade liberalization may not be the best alternative. In these instances, the policy implication is to allow for longer phases for reform implementation, in combination with specifically targeted support of low-income households.

Prior to generalizing these conclusions, it is wise not to overlook that it is not realistic to expect global trade reform negotiations could achieve full liberalization of tariffs and quota imports, and domestic support in agriculture. – but they also won't be restricted to staple grains.[10]

With this in mind, the hypothesis of partial reform effects (in staple grains) is addressed by analyzing the relative impacts of a 50 percent generic reduction in existing trade policies (tariffs and import quotas, export subsides, and domestic support), as well as well as reforms proposed under the WTO's DDA. The results of the significant differences of these partial reforms with the inherent market volatility are presented in the third and fifth column of table 9. The 50 percent reduction scheme produces discernable poverty effects in seven countries out of this sample of fifteen countries. Poverty reduction in the three Andean economies is shown to be significant, as well as the poverty increasing effects in Bangladesh, Indonesia, Brazil, and Mexico. Interestingly, this reform does not have a discernable poverty effect in the Sub-Saharan region.

The DDA results of change in poverty headcount (column 5 in table 9) do not have the same pattern as the uniform reform because of the differential tariff reduction between developed and developing economies, and the lesser reduction in agricultural domestic support (as indicated in the methodology section). The DDA proposal does not produce a discernable poverty effect on Sub-Saharan Africa and South East Asian (except Bangladesh, where there is a significant increase in poverty) countries. The most tangible poverty impacts of a DDA framework are felt in Latin-America. Brazil, Colombia, and Peru show a significant increase in poverty, and Mexico and Venezuela experience a discernable decrease in poverty.

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[10] As illustration, the comparison of the poverty effects of full liberalization in all goods with the staple grains induced effects yield significant differences in all cases (see tables 3.8 for relative magnitudes of poverty impacts).

5. Caveats

The measurement of poverty is the subject of ongoing debate. Recently Angus Deaton (Princeton University), Sala-i-Martin (Columbia University), and others have questioned the accuracy of World Bank estimates (Chen and Ravallion), as well as the sensitivity of poverty reduction predictions to the dollar-a-day threshold. The issue is that poverty estimates from the World Bank are based on household surveys, and as such it could be argued that they portray more accurately consumption and income patterns. Opponents to this metric contend that surveys are prone to error in design and implementation, they are sensitive to seasonal price variations, and have shown consistent under-reporting of income levels.

Sala-i-Martin (2002) advocates for poverty measures based on average income per person from national accounts data. According to this metric, poverty rates are considerably lower. The advantage of this approach is the accuracy of reported income levels. However, it has been argued that GDP-based poverty measures overstate the household income capacity by including private investment and government spending. The limitation of this measure in capturing some sorts of non-market income and consumption prevalent in developing-countries is particularly critical.

This study attempts to provide poverty-measures the potential to account for price fluctuations. However, by using the dollar-a-day measures for the calibration of the micro-simulation model, it takes a compromise about the assumptions of household and consumption behaviors. How much this analysis would change by implementing original conditions about the poverty levels based on national accounts data is not a clear call. It could be argued that price fluctuations due to market variability and price changes due to trade liberalization are equally relevant for people with incomes bellow one-dollar-a-day, or people who make just a little above that threshold. Conversely, for some regions income distribution is particularly sensitive to this threshold and endowments. All of which could translate in different results from the comparison analysis performed in this study.

6. Conclusions

This paper proposes the application of a stochastic simulation framework to look at the issue of price variability in agricultural markets and the poverty impacts of trade policy reform, by combining a CGE model of the global economy with a micro-household model. In spite of limitations in not modeling risk and household's inter-temporal decisions, this work generates a useful benchmark to which short-run poverty consequences of trade policies can be assessed. The focus is on staple grains as it represents a large share of the budget for the poorest households. We find that the short-run poverty impacts of *full* trade liberalization in world grains trade are statistically distinguishable from those due to inherent volatility in staple grains markets in 10 out of the 15 countries in this study.

In contrast to the full liberalization results, when we consider the impact of trade reform in grains under the WTO's DDA tiered formula proposal, it is not possible to distinguish the resulting poverty effects from those due to inherent market volatility in the countries of Sub-Saharan Africa and South East Asia (except for Bangladesh, where there is a significant increase in poverty). The most tangible poverty impacts of a tiered formula framework are felt in Latin-America, where Brazil, Colombia, and Peru show a significant increase in short-run poverty, and Mexico and Venezuela experience a discernable decrease in poverty.

Of course, in the overall assessment of trade reforms, it is important to bear in mind that the full realization of gains from trade reforms will only be realized in the long-term as a result of increased foreign competition and new investment. In addition, this paper has focused solely on grains markets. Extending it to other commodities is important before drawing broader conclusions. The proposed framework also provides a more general path for future empirical research on trade policy that takes into account price variability in assessing the poverty impacts of trade reform.

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Table 1. Import-Weighted Average Applied Tariffs, 2001.

	Agriculture	Processed Food	Agriculture and Processed Food	Other Primary[a]	Manufacturing
High – Income countries[b]	20.7	13.1	16.2	0.5	2.0
Developing countries	16.5	18.7	17.6	2.5	9.4
Middle Income countries	17.1	15.2	16.1	1.2	9.0
Low Income countries	14.9	27.3	21.5	6.0	10.6
East Asia and Pacific	31.4	20.2	26.1	0.8	9.8
South Asia	18.0	54.7	33.9	14.5	22.7
Europe (developing)	13.4	15.9	14.9	0.3	5.7
Middle East & N. Africa	9.5	18.0	13.6	3.5	9.3
Sub-Saharan Africa	15.3	20.5	18.3	2.0	12.0
Latin America & Carib.	8.5	11.4	10.1	2.1	7.6
WORLD	18.9	15.0	16.8	0.9	4.2

Source: Author's compilations from the GTAP database Version 6.

[a] Forestry, fishing, coal, oil, gas, and minerals.

[b] Intra-EU15 trade is ignored in calculating weights for determining tariff averages.

Table 2. Producer and Consumer Sectoral Aggregation

Consumption	Production	Original 57 GTAP sectors
Staple grains	Staple Grains	Paddy rice; Wheat; Cereal grains nec.
	Processed rice	Processed rice.
Livestock	Livestock	Cattle, sheep, goats, horses; Animal products nec; Raw milk; Wool, silk-worm cocoons.
	Processed Livestock	Meat: cattle,sheep,goats,horse; Meat products nec; Dairy products.
Other Food	Other Agriculture	Vegetables, fruit, nuts; Oil seeds; Sugar cane, sugar beet; Plant-based fibers; Crops nec; Vegetable oils and fats.
	Processed Food	Sugar; Food products nec; Beverages and tobacco products.
Non-durables	Non-durables	Forestry; Fishing; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Chemical,rubber,plastic prods; Motor vehicles and parts; Transport equipment nec; Electronic equipment; Machinery and equipment nec; Manufactures nec.
Durables	Durables	Coal; Oil; Gas; Minerals nec; Petroleum, coal products; Mineral products nec; Ferrous metals; Metals nec; Metal products; Transport nec; Dwellings.
Services	Services	Electricity; Gas manufacture, distribution; Water; Construction; Trade; Sea transport; Air transport; Communication; Financial services nec; Insurance; Business services nec; Recreation and other services; PubAdmin/Defence/Health/Educat.

Table 3. Regional Aggregation

Regions	Original 87 GTAP regions
Australia-New Zealand	Australia; New Zealand.
High Income East Asia	Hong Kong; Japan; Korea; Taiwan.
China	China.
South Asia	Rest of East Asia; Malaysia; Singapore; Rest of Southeast Asia; India; Sri Lanka; Rest of South Asia
USA Canada	Canada; United States.
Latin America	Rest of Andean Pact; Argentina; Uruguay; Rest of South America; Central America.
Eastern Europe	Austria; Belgium; Denmark; Finland; France; Germany; United Kingdom; Greece; Ireland; Italy; Luxembourg; Netherlands; Portugal; Spain; Sweden.
Western Europe	Switzerland; Rest of EFTA; Albania; Bulgaria; Croatia; Cyprus; Czech Republic; Hungary; Malta; Poland; Romania; Slovakia; Slovenia; Estonia; Latvia; Lithuania; Turkey.
Former Soviet Union	Russian Federation; Rest of Former Soviet Union.
Middle East North Africa	Rest of Middle East; Morocco; Tunisia; Rest of North Africa.
Sub Saharan Africa	Botswana; South Africa; Rest of South African CU; Tanzania; Zimbabwe; Rest of SADC; Madagascar; Rest of Sub-Saharan Africa.
ROW	Rest of Oceania; Rest of North America; Rest of FTAA; Rest of the Caribbean; Rest of Europe.
Regions for which there is available household survey data to conduct poverty analysis	
Bangladesh	
Brazil	
Chile	
Colombia	
Indonesia	
Malawi	
Mexico	
Mozambique	
Peru	
Philippines	
Thailand	
Uganda	
Venezuela	
Vietnam	
Zambia	

Table 4 Economic Indicators. Focus Regions of Poverty Analysis

	Population (in million) 2001	GDP per capita PPP (current $) 2001	Agriculture value added as a % of GDP 2001	Share of people in Poverty	Survey year
Bangladesh	140.9	1,613	24.1	29.1	1996
Indonesia	214.3	3,020	17.0	15.2	1993
Philippines	77.1	3,919	14.9	12.4	1999
Thailand	61.6	6,452	9.1	2.0	1996
Vietnam	79.2	2,103	23.2	37.4	1998
Brazil	174.0	7,571	6.1	5.1	1998
Chile	15.4	9,354	8.8	4.2	1998
Colombia	42.8	6,050	14.0	19.7	1998
Mexico	100.5	8,738	4.2	15.9	2000
Peru	26.0	4,699	8.5	15.5	1999
Venezuela	24.6	5,763	5.0	23.0	1998
Malawi	11.6	582	36.2	65.0	1998
Mozambique	18.2	*1,050	26.7	32.0	2003
Uganda	24.2	1,291	36.6	36.7	1999
Zambia	10.6	790	22.1	72.6	1998

*in 2002. Sources: FAO, World Bank: World Development Indicators, countries' surveys.

Table 5 Historical Staple Grains Production, and Variability Characterization.

	Staple Grains		
		Time series modeling	
	Average production (Million MT)	Normalized standard regression error [a]	Model ARIMA(p,d,q) [b]
USA - Canada	307.19	14.10	(4,1,0)
Latin America	87.02	5.75	({2},1,0) [c]
Western Europe	161.96	6.78	(0,1,1)
Eastern Europe	83.47	9.44	(1,1,0)
Former USSR	166.83	14.02	Linear Model
High Income East Asia	11.18	9.63	(1,1,0)
South Asia	155.09	5.66	(2,1,0)
China	246.7	4.76	({2},1,0) [c]
Middle East North Africa	24.82	15.00	(2,1,0)
Africa Sub Sahara	45.58	7.65	(1,1,0)
Oceania	20.39	24.33	(2,1,0)

Source: Author's calculations based on FAO data, Cereals, 1966-1995.

[a] Endpoints of a symmetric triangular distribution are constructed using these variances of production as: Endpoint = Mean $\pm \sqrt{6}$ standard regression error.

[b] *p* is the number of coefficients for the AR process, *d* is the number of differencing to make the series stationary, *q* is the number of coefficients for the MA process.

[c] a number in {} brackets indicates that the process only takes that lag, and not the previous one. e.g., the production series in China is fitted with an AR process that takes only lag 2.

Table 6. Vulnerability to Poverty, Measured as Ex Ante Mean and Standard Deviation of Poverty Changes Resulting from Grain Prices Fluctuation.

	Distribution of Poverty Changes			
	Percent change in poverty headcount		in thousands	
	Mean	Standard deviation	Mean	Standard deviation
Bangladesh	0.08	3.61	36	1481
Indonesia	0.05	2.87	17	939
Philippines	0.15	3.28	15	314
Thailand	0.08	0.98	0.4	7
Vietnam	0.06	1.13	18	336
Brazil	0.12	0.96	11	96
Chile	0.10	0.59	0.2	3
Colombia	0.06	0.79	5	68
Mexico	0.04	0.80	6	133
Peru	0.01	0.35	1	15
Venezuela	0.03	0.77	2	44
Malawi	0.03	1.39	2	105
Mozambique	0.28	2.87	16	168
Uganda	0.47	3.66	42	325
Zambia	0.02	0.34	2	27

Table 7. Welfare (Short-Run Effects [a]) from Fully Liberalizing Merchandise Trade.

Decomposition of Own and Foreign Policies Effects, and Sectoral Contribution.

	Equivalent Variation in income, 2001 $US million			Share of sectoral contribution		
		Changes in welfare due to:				
	TOTAL EV	Own lib.	Foreign lib.	Grains lib.	Other Agric & Food	Other Merchandise reform
Bangladesh	232	-182	414	-0.1	-0.4	1.5
Indonesia	1103	-495	1598	-0.1	0.3	0.8
Philippines	-65	-98	33	0.7	-0.1	0.4
Thailand	444	-1836	2280	0.2	1.4	-0.6
Vietnam	1685	360	1325	-0.01	0.1	0.9
Brazil	4828	-1252	6080	0.04	1.0	-0.02
Chile	759	-247	1006	-0.04	1.1	-0.1
Colombia	-141	-296	155	0.4	-1.8	2.4
Mexico	-483	634	-1117	-0.2	-0.03	1.2
Peru	171	-95	266	-0.3	0.9	0.4
Venezuela	-135	-62	-73	0.2	0.7	0.1
Malawi	86	-10	96	-0.02	0.9	0.1
Mozambique	-9	-13	4	0.1	0.9	0
Uganda	-22	-16	-6	0.2	0.6	0.2
Zambia	25	-12	37	0	0.1	0.9

[a] Capital, land, and self-employed labor are immobile and the returns to these factors are combined into sectoral profits, corresponding to agricultural and on agricultural profits reported in the household surveys. Wage and salaried labor are imperfectly mobile among agricultural and non-agricultural uses.

Table 8. Poverty Impacts (Short-Run) of Full Merchandise Trade Liberalization, and Isolated Effect of Staple Grains Liberalization.

	Change in Poverty Headcount				
	Percentage change		in thousands		
	All Goods lib.	Grains lib.	All Goods lib.	Grains lib.[a]	
Bangladesh	-2.0	0.6	-816	256	(-31)
Indonesia	0.6	0.9	204	294	(144)
Philippines	-0.2	0.3	-18	25	(-138)
Thailand	-0.5	0.1	-2	1	(-62)
Vietnam	-4.2	0.2	-1,251	52	(-4)
Brazil	62.6	3.2	5,562	281	(5)
Chile	-1.0	0.2	-6	1	(-22)
Colombia	-0.4	-0.2	-32	-20	(63)
Mexico	2.5	1.7	401	274	(68)
Peru	0.5	-0.2	21	-9	(-44)
Venezuela	-0.4	-0.1	-24	-5	(22)
Malawi	-2.6	0.1	-198	5	(-3)
Mozambique	-0.7	0.4	-40	21	(-54)
Uganda	1.3	1.2	113	110	(97)
Zambia	0.1	0.02	10	2	(18)

[a] Numbers in parentheses show poverty impacts of grains liberalization as a percentage of all goods liberalization.

Table 9. Comparison of (Grain) Trade Reform Poverty Impacts versus Supply Variability Induced Vulnerability.

(Entries in table correspond to calculated T-statistic of Two-independent samples, and numbers within parentheses are change in poverty headcount (in thousands))

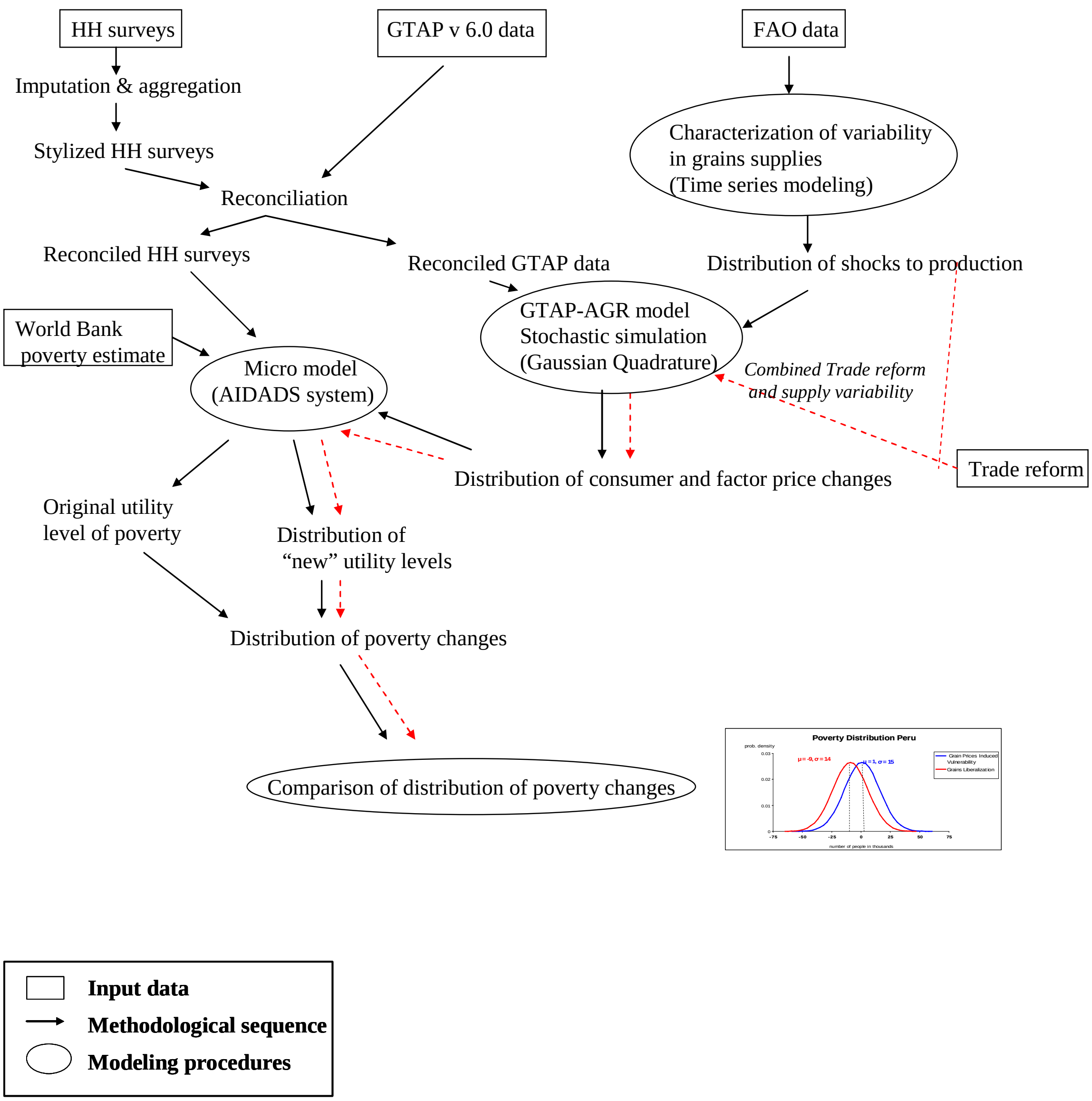
	Grains trade reform		50% of grains trade reform		DDA tiered formula proposal (grains reform)	
Bangladesh	3.31	(256)	2.73	(217)	3.28	(253)
Indonesia	6.48	(294)	2.29	(115)	0.34	(31)
Philippines	0.71	(25)	-0.15	(13)	-0.21	(12)
Thailand	1.21	(1)	-0.81	(0)	0.32	(1)
Vietnam	2.27	(52)	-0.74	(7)	-1.24	(-1)
Brazil	22.06	(281)	5.88	(83)	13.25	(68)
Chile	5.06	(1)	0.84	(0)	0.99	(0)
Colombia	-8.10	(-20)	-4.36	(-8)	2.59	(13)
Mexico	41.80	(274)	18.79	(126)	-2.36	(-8)
Peru	-15.41	(-9)	-8.09	(-4)	3.35	(3)
Venezuela	-3.60	(-5)	-2.18	(-2)	-3.05	(-4)
Malawi	0.64	(5)	-0.23	(1)	-0.34	(0)
Mozambique	0.67	(21)	-1.05	(8)	-1.40	(6)
Uganda	4.47	(110)	-0.82	(30)	-1.91	(14)
Zambia	-0.08	(2)	-1.46	(0)	-1.44	(0)

Significant at α = 0.05, Tc two tails =1.975

Significant at α = 0.10, Tc two tails =1.65

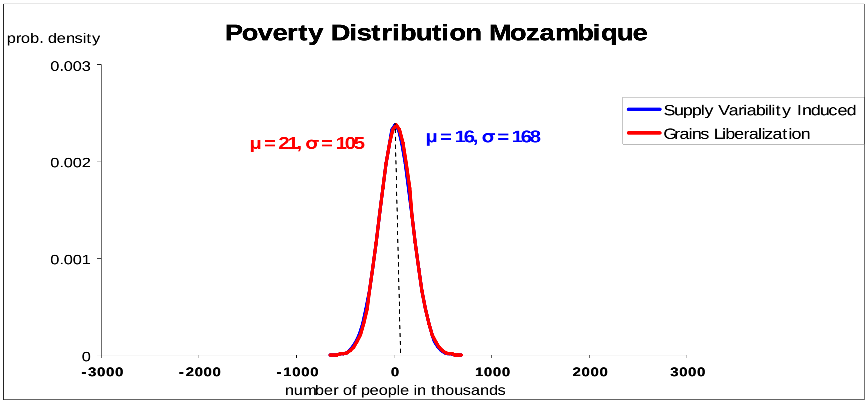
NOT significant from staples grain prices induced volatility

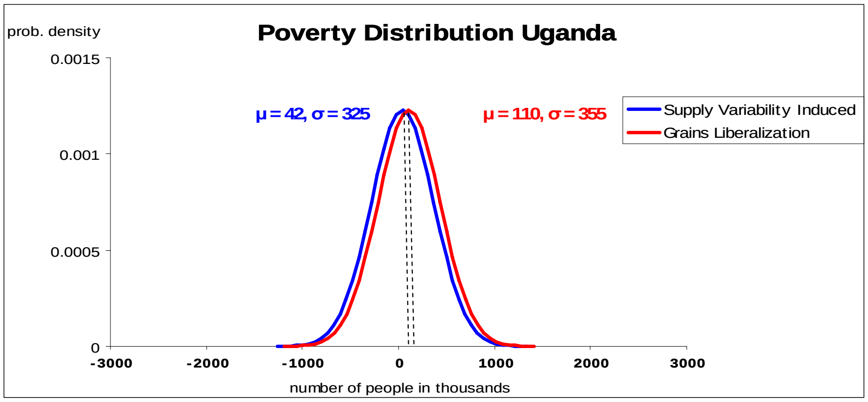
Figure 1. Trade reform versus Inherent Volatility in Grains Markets Poverty Impacts — Description of the Framework.

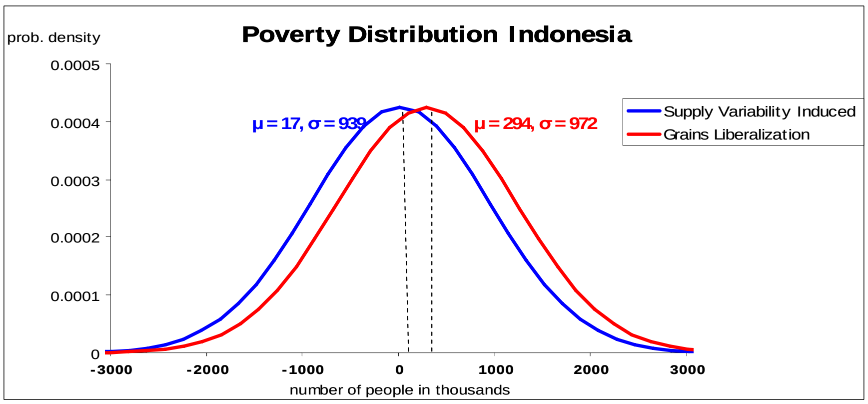


Source: Modified after Ivanic (2006) by the implementation of the stochastic structure, and the underlying comparison of the distribution of poverty changes. Additional attention is placed to explicitly differentiate input data from methodological procedures.

Figure 2. Ex Ante Distribution of Poverty Changes Induced by Supply Variability, and Trade Reform Poverty Changes.







Appendix 1. CGE model – The GTAP-AGR model

We employ a new variant of the GTAP model (Hertel, 1997) that is specifically oriented to analyzing agricultural markets, namely the GTAP-AGR model (Keeney and Hertel 2005). We use the standard GTAP model assumptions of perfect competition and constant returns to scale in production activities, a Constant Difference of Elasticities (CDE) demand system which permits differential price and income responsiveness across countries, and bilateral international trade flows handled through Armington elasticities by which products are differentiated by country of origin. These Armington elasticities are region-specific, and are econometric estimates at the 57 GTAP commodity level based on the elasticity of substitution in consumption among imported goods from different sources (Hertel et al. 2003).

The GTAP-AGR model introduces a number of modifications to the way agriculture is handled in the standard GTAP model, based on recent econometric studies. First, it incorporates a region-specific elasticity of land transformation amongst agriculture uses. While land is specific to agriculture in the GTAP model, the new parameters in GTAP-AGR make land less responsive within the agricultural sector to changes in relative agriculture prices. Second, GTAP-AGR incorporates region-specific labor and capital supply elasticities in constant elasticity of transformation functions that allocate their use between agricultural and non-agricultural sectors. The limited mobility of labor allows for wage differentials between agriculture and non-agricultural sectors, and capital too is allowed to receive return differentials between agricultural and non-agricultural activities. These supply elasticities are based on estimates from the OECD (2001). Third, the GTAP-AGR model also allows for substitution among farm-owned and purchased inputs, and between the two, by calibrating each sector's constant elasticity of substitution cost function to the region-specific Allen elasticities of substitution provided by OECD estimates. Fourth, the livestock production function is modified to capture more realistic substitution possibilities in feed demand, by modeling the substitution possibilities for feedstuffs as an additional CES nest in the sector's cost function. This livestock production function is parameterized based on a three-stage model describing the behavior of European livestock producers, composite feed mixers, and grain producers (Surry 1990). Finally, the GTAP-AGR consumer demand system is re-specified assuming separability of food from non-food commodities, and calibrated in line with a recent set of price and income elasticities from a cross-country study (Seale, Regmi and Bernstein 2003).

Appendix 2. Micro-simulation model

Hertel et al.'s (2004) framework adopts an implicitly directly additive demand system (AIDADS of Rimmer and Powell 1992a, 1992b, 1996) to obtain a utility function for each country by implementing the estimation framework developed by Cranfield et al. (2004).

The optimization problem of the household model involves maximizing per capita utility, subject to a per capita budget constraint, based on the households' overall endowments:

$$\max_{x_{1k},\ldots,x_{ik},\ldots,x_{nk}} \underset{i}{U}\left(x_{ik}, u_k\right) \tag{A.1}$$

s.t.
$$\sum_{i=1}^{n}\left(p_i x_{ik}\right) = Y^k = \sum_f W_f \bar{E}_f^k - \sum_f \delta_f P_f \bar{E}_f^k + T^k Y \tag{A.2}$$

$$\sum_{i=1}^{n} \frac{\left[\alpha_i + \beta_i \exp(u_k)\right]}{\left[1+\exp(u_k)\right]} \quad \ln\left(\frac{x_{ik} - \gamma_i}{A\exp(u_k)}\right) = 1 \tag{A.3}$$

where *i* indexes the commodities, *k* households, and *uk* per capita household utility.

In this formulation, (A.3) defines the implicitly additive AIDADS utility function with parameters $\alpha_i, \beta_i, \gamma_i$ and *A*. Parameter γ_i is the subsistence quantity for good i, α_i, and β_i represent estimates of the bounds of the discretionary budget shares, at low income levels, and high income levels respectively.

Equation (A.2) is the *per capita* budget constraint, with income defined net of depreciation and inclusive of any transfers. The notation for the income expression is as follows: W_f is the wage paid to endowment $\bar{E}_f^k$, δ_i is the geometric rate of depreciation for endowment $\bar{E}_f^k$ (zero for non-capital items), P_f is the cost of replacing depreciable endowment *f* (the capital goods price), and T^k is the transfer rate for household *k*, which is assumed to be a constant share of net national income, *Y*.

The results of trade liberalization and volatility in production will alter the wages associated with each endowment, the price of capital goods and transfers. The resulting level of income for household *k* can be computed using equation (A.2). Once the new income level is known, it may be combined with the new vector of commodity prices to compute expenditure on each good, and hence individual demands. Equations (A.1 and A.3) are then used to compute each household's utility. Based on the post-liberalization utility level, and the distribution of utility post-stochastic production, the change in poverty headcount can be calculated.