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Are The Poverty Effects of Trade Policies Invisible?

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Beginning with the WTO's Doha Development Agenda and establishment of the Millennium Development Goal of reducing poverty by 50 percent by 2015, poverty impacts of trade reforms have become central to the global development agenda. This has been particularly true of agricultural trade reforms due to the importance of grains in the diets of the poor, presence of relatively higher protection in agriculture, as well as heavy concentration of global poverty in rural areas where agriculture is the main source of income. Yet some in this debate have argued that, given the extreme volatility in agricultural commodity markets, the additional price and therefore poverty impacts due to trade liberalization might well be indiscernible. This paper formally tests the "invisibility hypothesis" using the method of stochastic simulation in a trade-poverty modeling framework. The hypothesis test is based on the comparison of two samples of price and poverty distributions. The first originates solely from the inherent variability in global staple grains markets, while the second combines the effects of inherent market variability with those of trade reform in these same markets. Results, at the national and stratum level indicate that the short-run poverty impacts of full trade liberalization in staple grains trade worldwide, are distinguishable in only four of the fifteen countries, suggesting that impacts of more modest agricultural trade reforms are indeed likely to be invisible in short run. Countries that show statistically significant short run impacts are the ones characterized by high staple grains tariffs and/or a moderate degree of grain markets variability. Within each country, results are heterogeneous. In two thirds of the sample countries, agriculturally self-employed poor experience statistically significant poverty impacts from trade liberalization. However, this figure is under a third for all the other strata. Agricultural trade reform, computable general equilibrium, poverty headcount, volatility, stochastic simulation, hypothesis testing. JEL codes: C12, C68, F17, I32, Q17, R20

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The authors wish to thank Antoine Bouet, Paul Preckel, William Masters, Alain de Janvry and three anonymous referees for helpful suggestions which led to significant improvements of this manuscript. A supplemental appendix to this article is available at https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3386

THE WORLD BANK ECONOMIC REVIEW, VOL. 25, NO. 2, pp. 190–211 doi:10.1093/wber/lhr014
Advance Access Publication May 17, 2011

World Trade Organization's (WTO) Doha Development Agenda, and the Millennium Development Goal to reduce poverty by 50 percent by the year 2015, served to bring the poverty impacts of trade reforms into central focus for global policy makers. This has been particularly true of agricultural trade reforms due to the importance of grains in the diets of the poor, relatively higher protection in agriculture, as well as the heavy concentration of global poverty in rural areas where agriculture is the main source of income. Three quarters of the world's poor reside in rural areas (World Development Report 2008), mostly depending for their livelihoods on agriculture; it is therefore hardly surprising that changes in primary commodity prices have been identified as one of the most important linkages between international trade and poverty (Winters 2000). Agricultural commodity prices are of course inherently volatile, due to the combination of inelastic demand and supply, high perishability, high transport costs, and exposure to random weather shocks. The recent 2007/2008 food price spike,in fact, has been estimated to have thrown more than one hundred million people temporarily into poverty (Ivanic and Martin 2008).

Given this background volatility in agricultural prices and poverty, some have argued that the additional poverty impacts due to trade liberalization might well be indiscernible. Indeed, in a critique of an early draft of Clinés (2004) book on trade policy and poverty, Rodrik (2003) made the point that the impacts of reforming agricultural protection in developed economies on world prices are likely to be dwarfed by the inherent volatility of agricultural markets. Similar sentiments surfaced in the context of the debate over the poverty impacts of trade liberalization under the Doha Development Agenda (Hertel and Winters 2006). This paper terms this assertion, the '*invisibility hypothesis*'. The goal of this paper is to formally test the invisibility hypothesis using a model of global trade, linked to poverty modules for fifteen developing countries.

It is important to point out up front that statistically failing to reject the invisibility hypothesis by no means implies that agricultural trade reform is economically irrelevant. Even in cases where the long run impacts of agricultural trade reform are large, and of lasting importance, the short run impacts of such reforms on poverty might be statistically indiscernible due to the extreme volatility in international agricultural markets. As witnessed in recent years, commodity price swings of more than one hundred percent within a given year are not uncommon. These swings can themselves have a devastating effect on the poor – and they can also benefit those households which are net sellers of agricultural products. Given the significance of such commodity market volatility for the poor, it is important to couch agricultural trade reforms in this context. Also, the fact is that such reforms do not take place in a vacuum, and the presence of extreme market volatility will shape the way the world perceives them. It is important that those advocating agricultural trade reforms not overstate the near term impacts, which may indeed be dominated by other factors. On the other hand, it is also important to consider that, while the poverty changes induced by trade reforms may in some cases be smaller than those swings caused by inherent commodity market volatility, the gains from trade policy reforms represent permanent changes and are therefore likely to be of greater economic significance than the transitory changes induced by annual market volatility.

Previous literature on poverty impacts of trade reforms in the presense of inherent price variability is limited (Valenzuela 2009). Bourguignon et al. (2004) developed a stylized framework to assess the impact of export price variability on household income volatility. The related topic of the impact of higher food prices on poverty has also drawn attention (de Janvry and Sadoulet 2010; Ivanic and Martin 2008) as have the impacts of trade reforms on income distribution (Robbins 1996; Lunati and ÓConnor 1999). However, none of these authors have offered a formal test of the invisibility hypothesis. The contribution of this paper is to provide such a test. The *invisibility hypothesis* is formulated as follows: *Due to the high degree of volatility inherent in agricultural commodity markets, the incremental impact of agricultural trade liberalization on agricultural prices and the ensuing poverty impacts will be statistically invisible.*

The focus is on a subset of commodities – staple grains – which are often subject to high levels of protection, and which also represent a large share of the budget for the poorest households. Volatility in staple grains production is modeled by sampling from a distribution of productivity shocks derived from a time series analysis of Food and Agriculture Organization (FAO) production data. This supply-side volatility is implemented in a Computable General Equilibrium (CGE) framework – the agriculture-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 changesin global trade policies as well as uncertainty in world grain yields, while retaining economy-wide consistency. Our analysis concentrates on the implications of these earnings and price changes, for the utility of households in the neighborhood of the poverty line, asking whether they might fall below this poverty line or be lifted out of poverty as a result of these commodity market shocks. By aggregating across the diverse socio-economic groups within the economy, a conclusion about the change in national poverty headcount can be inferred for each draw from the agricultural productivity distribution. The resulting distribution of poverty headcounts is contrasted with the same distribution when trade reforms are implemented in combination with the inherent commodity productivity volatility. The first set of results, stemming from the inherent variability in global staple-grains markets, is referred to as the *stochastic baseline scenario*, while the combined effects of the inherent market variability and trade reforms is referred to as the *stochastic policy reform scenario*. While the model is general equilibrium in nature, price volatility only in the staple grains markets is considered and therefore, to be consistent, the trade reforms are also only implemented in the staple grains sector. A further qualification stems from the fact that this is a static approach. Clearly a dynamic stochastic model would be preferred. This would permit us to distinguish permanent from transient shocks, with important implications for agents' responses to these different types of shocks. However, this would introduce additional complexities that exceed the scope of this paper.

In order to get an adequately broad representation of the diverse economies and circumstances in which the world's poor live, this analysis is undertaken for fifteen developing countries in South Asia, Latin America and Sub-Saharan Africa. The remainder of this study is organized as follows. The methodology is described next (Section I). Section II presents the results for the moments of distributions for variables driving poverty headcounts changes before formally testing the invisibility hypothesis. It also provides a discussion of sensitivity of our results to the assumption of exogenous trade policy changes. Caveats, conclusions and policy implications are discussed last (in Section III).

I. Methodology

One approach to testing the invisibility hypothesis would be to develop a single country trade/poverty model in great detail and test this hypothesis in the context of that particular country. This is attractive, as it would allow development of the poverty component in considerable detail (see Hertel and Winters 2006, for ten country case studies undertaken to assess the national impacts of WTO reforms). However, there are several problems with this approach. Firstly, using a national model makes it difficult to generate stochastic global price shocks in a consistent manner. Secondly, WTO agricultural reforms typically entail significant liberalization in developed markets, so without a global framework it is problematic to accurately assess the poverty impacts of such reforms on developing countries. Finally, readers would very likely argue that the results were specific to the country under investigation, if such tests of the invisibility hypothesis were undertaken only for an individual country. Therefore, a multi-country approach to testing the invisibility hypothesis is adopted. The cost of doing so is that the poverty analysis is necessarily rather simple and symmetric across countries.

Poverty Headcount Analysis

The analysis here relies on the trade/poverty approach outlined in Hertel *et al.* (2009). Those authors focus on poverty headcount changes in diverse household population strata across a range of developing countries. A first order approximation to such poverty headcount changes may be written as follows (the hats denote percentage changes in the associated variables):

$$\hat{H}_{rs} = -\varepsilon_{rs} \cdot \hat{y}^{p}_{rs} = -\varepsilon_{rs} \cdot \sum_{j} \alpha^{p}_{rsj}(\hat{w}_{rj} - \hat{C}^{p}_{r}). \tag{1}$$

Here, the index r denotes *region* (focus country), s the population *stratum*[1] and the superscript p signifies that the variable in question is associated with earnings and consumption patterns at the *poverty level* of utility. Any shock to the economy that alters the after-tax returns to factor j (w_{rj}) and/or the prices of consumption goods, will affect the poverty level of income (y^{p}_{rs}), the cost of living for poor households (C^{p}_{r}) and therefore strata poverty headcounts (H_{rs}).

The term $\sum_j \alpha^{p}_{rsj}(\hat{w}_{rj} - \hat{C}^{p}_{r})$ in equation (1) is the percentage change in real factor income in stratum s of region r, taking into account the cost of living changes for households at the poverty line in stratum s of region r. The change in cost of living at the poverty line in region r, denoted $\hat{C}^{p}_{r}$, is the change in household expenditure required to keep utility constant at its poverty level, once a new set of prices is obtained. This change is derived by solving the household expenditure minimization problem at the new prices, while keeping utility fixed at the poverty level. Thus households are permitted to alter their optimal consumption bundle in response to the new commodity prices.

Apart from the "driver" variables (after-tax factor earnings and commodity prices), two more elements play an important role in determining poverty headcount impacts. Coefficient α^{p}_{rsj} is the share of factor earning j in total income for households at the poverty line, in stratum s of region r. For a given increase in factor earnings (e.g., unskilled agricultural labor), a stratum that obtains 90 percent of its income from this concerned factor, will experience a greater income rise than one with only 10 percent of its income attributable to that factor. Since these are shares, the summation over factor earnings types for any given stratum equals one ($\sum_j \alpha^{p}_{rsj} = 1$). The values for α^{p}_{rsj} in our sample of 15 countries are obtained from household surveys and range from 0 to 0.99 (as shown in Appendix Table A1, available at https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3386). The second coefficient of interest in equation (1) is ε_{rs}, the poverty elasticity with respect to income in stratum s of region r. The higher the poverty elasticity, the greater the headcount reduction from a given increase in income for households at the poverty line in that particular stratum. Estimates of ε_{rs} range from 0.0006 to 8.9 (Appendix Table A2), and vary widely by stratum and country.[2]

The change in total poverty headcount in a region is obtained by summing over stratum headcounts; therefore, the percentage change in national headcount can be written as share weighted sum of percentage headcounts changes

1. There are seven strata: Agriculturally self-employed, non-agriculturally self-employed, rural wage labor, urban wage labor, rural diversified, urban diversified and transfer stratum.

2. More details on the elasticities can be found in Verma et al. (2011).

at the stratum level:

$$\hat{H}_r = \sum_s \beta_{rs} \cdot \hat{H}_{rs}, \tag{2}$$

where the shares (β_{rs}) are the share of stratum s in total poverty in the region r. β_{rs} plays an important role in determining how the stratum headcount changes get translated into the aggregate regional headcount.[3] The initial equilibrium values for all of these coefficients are estimated from household survey data for the 15 focus countries (Hertel *et al.* 2004) and are reported in Appendix Table A2.

Substituting equation (1) in (2) gives the regional headcount in terms of its driving factors

$$\hat{H}_r = -\sum_s \beta_{rs} \cdot \varepsilon_{rs} \cdot \sum_j \alpha^p_{rsj}(\hat{w}_{rj} - \hat{C}^p_r), \tag{3}$$

(3) can be further decomposed into changes due to pre-tax factor earnings ($\hat{w}^m_{rj} = \hat{w}_{rj} + \hat{T}_r$), income tax changes ($\hat{T}_r$) designed to ensure revenue neutrality of policy and the cost of living changes due to changed consumption prices, evaluated relative to the change in net national income:

$$\hat{H}_r = -\sum_s \beta_{rs} \cdot \varepsilon_{rs} \cdot \sum_j \alpha^p_{rsj}\left(\hat{w}^m_{rj} - \hat{y}_r\right) + \varepsilon_r \cdot \hat{T}_r + \varepsilon_r(\hat{C}^p_r - \hat{y}_r). \tag{4}$$

The first term in equation (4) can be termed the earnings effect and involves the changes in factor earnings of the poor relative to national income. The second term is the tax effect and the last term identifies the effect of changes in cost of living relative to net national income. The term ε_r is the regional poverty elasticity and is defined as the poverty share-weighted sum of strata poverty elasticities ($\sum_s \beta_{rs} \cdot \varepsilon_{rs}$). Any increase in taxes or relative cost of living raises poverty headcount in a region while increased relative factor incomes work towards poverty reduction. Overall, the poverty headcount in stratum s of country r falls when real income increases; the amount by which it falls depends on the density of the population in the neighborhood of the poverty line.

Equation (4) offers a useful framework for analyzing the poverty impacts of trade and commodity market volatility. There are, however, some important limitations to its use which deserve a mention. Foremost among these is the

3. Consider for expository purposes that the poverty headcount for the rural diverse stratum for both Brazil and Uganda fell by 50 percent and other strata were unaffected ($\hat{H}_{rs} = 0 \; \forall s \neq ruraldiverse$), then regional poverty headcount in Brazil would fall by a mere 1.5 (0.03 x 50) percent while in Uganda by a 37.5 (0.75 x 50) percent. The results are so diverse due to the big difference (0.03 versus 0.75) in the share of poverty population concentrated in the rural diverse stratum in the two countries, as can be seen from Appendix Table A2.

static composition of the strata as the earnings specialization of households isn't allowed to change; large shocks may induce a household to switch employment (e.g. moving from agriculture to non-agriculture), although this is less likely in the short run. In addition, the focus is only on changes in the poverty headcount; ignoring higher order measures, such as the poverty gap. The virtue of this simple approach is that it can be readily implemented across a wide range of household strata and countries, thereby permitting us to generalize our findings.

Global General Equilibrium Model

To calculate the impact of trade policy reforms on poverty headcount as per equation (4), one must first determine the impact of trade policy reforms on the poverty "drivers", w_{rj} and C_r^p. The inability of partial equilibrium frameworks to predict the changes in economy-wide factor returns, which play a very prominent role in the analysis, forces us to use a CGE model in our analysis. One of the main criticisms of CGE models is the absence of validation (Kehoe *et al.* 1995). Accordingly, special attention is devoted to validating the model with respect to staple grains markets.

This study employs the GTAP-AGR model of Keeney and Hertel (2005) which is explicitly designed to focus on issues of agricultural trade liberalization. (See Appendix I for details on the model structure and data sources used). A short-run factor market specification is used such that land is commodity-specific, capital is sector-specific and labor is imperfectly mobile between agriculture and non-agriculture sectors. The degree of inter-sector mobility is determined by the choice of relevant parameters in the model. These are set, based on evidence on labor mobility from the OECD (2001). In addition, the model is modified to accommodate the replacement of lost tax revenue from trade reforms, in the form of a non-distorting uniform *ad valorem* tax on income, making each scenario fiscally neutral.

Stochastic Simulation and Model Validation

The credibility of any simulation model hinges very much on whether the model can produce reliable predictions for key endogenous variables, based on historical shocks. In practice, there are very few natural experiments involving trade policy reforms. WTO rounds are typically concluded once every decade or two, and their implementation is gradual and fraught with controversy. National reforms are sometimes more clear-cut; however, their effects are often confounded with other significant events (e.g., a financial crisis, or a recession, etc.). Therefore a different type of natural experiment which is somewhat unique to the staple grains markets, is used for validation – the focus is on how well the model captures the economic impacts of random historic volatility in agricultural productivity, largely induced by weather-related shocks. Given the relative stability of demand for subsistence goods such as staple grains, demand-side volatility is ignored here; characterizing only supply side volatility in the staple grains markets and thereupon asking whether the model is capable of reproducing observed price volatility in these same markets. If the model can accurately characterize inter-annual price volatility in response to supply side shocks then it is also a valid tool for looking at the short run impacts of tariff shocks in these same markets.

The validation approach involves using production shocks derived from the residuals of time series models of FAO grains production data. By sampling from the derived distribution, the stochastic simulation seeks to mimic the randomness inherent in these markets. Solving the CGE model repeatedly, each time with a different set of productivity draws, produces the resulting distribution of price changes for each region. The validation then involves comparing the model results for grain price variation, with FAO observed price variation in each region. With the aim of improving the CGE replication of observed FAO price variability, the model's consumer demand elasticities were adjusted for a few regions; details of the approach are given in the next subsection. After ensuring the historic price variation is faithfully replicated, one can concentrate on contrasting the poverty headcount distributions associated with the *stochastic baseline* and *stochastic policy reform scenarios* and testing for statistical difference between these two sets of results.

Characterizing Volatility. Tyers and Anderson (1992) characterize uncertainty in global food markets by sampling from a distribution of supply shocks. Valenzuela et al. (2007) use this approach to validate a model of global wheat trade. The same approach has been used here. Autoregressive Moving Average (ARMA) models are used to characterize systematic changes in staple grains production, using the ARMA residuals to define the distributions of productivity shocks. This specification is appealing in modeling grain crops production because past values appear to carry a great deal of information about current values and prediction errors arise largely from weather-related shocks to production. Staple grains production data from the FAO for the period 1991 to 2006 (FAOSTAT)[4] is used to calculate the productivity shocks for aggregate regions.[5] The 15 focus countries inherit the shocks from their respective parent region.

The model selection is guided by the significance of the AR and MA components, the Akaike Information Criteria (AIC), and autocorrelation in residuals for alternative model specifications. The *normalized standard deviations* of the production residuals from the estimated time series models are used to create a distribution reflecting random regional productivity variation.

4. While paddy rice and wheat are the same across GTAP and FAOSTAT terminology, the Coarse-grains category under GTAP covers barley, maize, mop corn, rye, oats, millet, sorghum, buckwheat, quinoa, fonio, triticale, canary seed, mixed grain and cereals nes. reported in FAO data.

5. Calculations using FAOSTAT data show that measures of observed volatility in output vary considerably depending what aggregation of crops and regions is used. Generally speaking, the higher the level of aggregation, the lower is the volatility that the CGE model is adjusted to replicate. The aggregation scheme for regions is provided on Appendix Table A4.

The greatest production volatility is seen in Russia[6], Sub-Saharan Africa and Eastern Europe. With the assumption that productivity follows a symmetric triangular distribution, the end points of this distribution are determined by the formula: *mean* $\pm \sqrt{6} \times$ *productivity standard deviation*. This estimated distribution of productivity shocks for each region provides the basis for implementing the *stochastic baseline scenario*.

The methodology involves sampling from this distribution of productivity shocks and solving the CGE model repeatedly. The results for each solve of the model are stored and the means and standard deviations of the stored results for all endogenous variables are calculated. The sampling is done by means of Gaussian Quadrature (GQ), a numerical integration technique developed as an alternative to Monte-Carlo simulations, and implemented for GTAP models by Pearson and Arndt (2000). The GQ technique is chosen instead of the more traditional Monte Carlo approach, as it significantly reduces the number of simulations while still preserving the accuracy of the resulting means and standard deviations for endogenous variables (DeVuyst and Preckel 1997).

The validity of evaluating the impacts of trade liberalization in the context of a volatile grains market environment critically depends on the capability of the CGE system to replicate historical price variability. This capacity of the model is assessed by comparing the model simulated volatility for staple-grains prices, to FAO-observed volatility (Table 1). Since staple grains represent a composite of many commodities, a range of historic price volatilities from the FAO data base is reported in the first column of this Table. For example, in Bangladesh, price volatility of rice, wheat and coarse-grains, as measured by the normalized standard deviation of ARMA residuals, ranges from 5% to 12%. In the Philippines, this is a smaller range (10% to 13%). Initial results indicated that the model overstated price volatility for Philippines, Bangladesh, Colombia, Peru, Venezuela, Malawi and Mozambique; while it understated the same for Thailand. Aiming to replicate the price volatility for these regions more closely, the consumer demand elasticities in these regions were re-calibrated.[7] Specifically, demand elasticities were increased for regions where price volatility was over-predicted by the model, while they were reduced for Thailand. Elasticities were also increased for all the rest of Sub-Saharan African regions, as the model predicted unusually high price volatility for these countries.

The price volatility results, after adjusting the elasticities, are reported for comparison (Table 1). This calibration process enables the CGE model to replicate the FAO data price variation in most cases (with the exceptions of Thailand, Colombia and Venezuela). For Colombia and Venezuela the model over-states price volatility. This could be due to the Andean Price Band

6. This region includes Russia and all the constituent states of the former Soviet Union.
7. More details and justification for this approach is provided in Verma (2010).

TABLE 1. Historic versus Model Generated Price Volatility and Associated Percentage Changes in Poverty Headcount

	Historic Volatility Range	Model Generated Volatility Results	Mean Percent Change (stochastic baseline)**
Bangladesh	5-12	11	0.19
Indonesia	9-19*	11	0.07
Philippines	10-13*	13	−0.10
Thailand	11-14	7	0.02
Vietnam	~	7	0.18
Brazil	11-20	12	0.09
Chile	7-21	11	0.03
Colombia	4-10	14	0.07
Mexico	7-9	9	0.12
Peru	6-15	15	0.08
Venezuela	6-11	18	0.12
Malawi	21-30	23	−0.01
Mozambique	16-20	19	0.12
Uganda	~	22	−0.07
Zambia	~	19	0.12

Source: FAO Price-Stat Data 1991-2006, Model generated price variation results and Authors Calculations using Model Simulation Results

* FAO Price data on wheat is not available for Indonesia and Philippines; so the range reflects the price volatility of rice and coarse grains only.

~ FAO Price data on none of the crops is available for Vietnam, Uganda and Zambia.

** These changes in Poverty Headcount in absence of any policy shock arise as a result of inherent changes in agricultural commodity prices.

System policy which was implemented in 1995 and involved variable tariffs in Peru[8], Colombia, Venezuela and Ecuador aimed at restricting price fluctuations in these markets (Villoria *et al.* 2002). The model used here does not reflect these country specific policies and therefore misses these effects.[9] For Thailand the model under-predicts price volatility – a problem similar to that faced by Valenzuela *et al.* (2007) who found that the same type of global CGE model under-predicted price variations for most exporters (Thailand is a major exporter of rice). The base case scenario here does not incorporate the endogenous response of border policies to changes in global market condition such as the export bans and import policy changes which arose in the context of the 2007/2008 food crisis. These policies tend to exacerbate price volatility – particularly for exporters (see Valenzuela *et al.* for more details). Implications of such policy endogeneity are briefly explored in Section III below.

8. In the case of Peru, the model generated price variation reaches the upper limit of the observed price variation range.

9. In principle it would be desirable to model these policies explicitly. However owing to the diverse range and complexity of policies across countries, such an endeavor is better-suited to a country case study approach.

With mean zero agricultural productivity shocks under the stochastic baseline, mean zero outcomes for most model variables are to be expected. The last column of Table 1 in fact shows that the mean changes for the poverty headcounts[10] are less than 1 percent.

Modeling Staples Trade reforms. The year 2001 is adopted as the benchmark, as it is the base year for Doha proposals on tariff cuts and also the base year for the GTAP version 6.1 data (Dimaranan 2006). The first column of Table 2 shows tariffs in the staple grains sector for all of the 15 focus countries. Mexico has the highest import tariffs for staple grains, followed by Thailand and Peru. Overall, the focus countries have much lower tariffs on staple grains than do the non-focus countries (rest of world). This study considers a scenario of trade liberalization which involves the complete removal of tariffs in all focus, as well as non-focus countries.[11] Though our simulations focus on full liberalization in all countries, under realistic trade negotiations different countries may undertake different levels of agricultural tariff reductions. To be consistent with the stochastic baseline simulations (variability is restricted to staple grains production), trade reforms in other sectors of the economy are not considered. Thus, our *stochastic policy reform* scenario is the combined effect of inherent market variability and the complete elimination of effectively applied tariffs in staple-grains market.

II. Results

Elimination of the import tariffs for staple grains is expected to result in lower consumer prices in countries with high initial tariffs (see Table 2). Since the average import tariff in the focus regions is about 11 percent, countries with higher than 11 percent tariffs are expected to experience greater consumer price reductions, and therefore potential greater poverty reductions (abstracting from the earnings side of the poverty story). We focus on the impacts of trade reform in the context of the stochastic simulations.[12]

A good starting point – before focusing on poverty headcount distributions, at the aggregate regional as well as the disaggregated stratum levels – is the

10. Any big numbers in thousands of units can be explained by the presence of a big poverty base (Appendix Table A5). Note that as the percent change in poverty headcounts is the average percentage change in the variable across 22 simulations, the decomposition of results though along the lines of deterministic setup is not as straightforward. Most of the analysis therefore focuses not on what is driving the means but on a more relevant question that the stochastic framework can answer: *whether the distributions with and without reforms are different.*

11. The focus is on tariffs-only policy reform as data on domestic support and export subsidies is not available on a consistent global basis. Croser and Anderson (2010) using a partial equilibrium framework and a recent World Bank comprehensive set of indicators of distortions to agricultural incentives (Anderson and Valenzuela 2008) found that border measures in agricultural markets account for more than 85 percent of global loss of welfare.

12. Readers interested in a detailed deterministic analysis of the impacts of tariff reform alone are referred to Appendix II.

TABLE 2. Import Tariffs on Staples and Mean and Standard Deviations for Staples Prices (Percentage Change), Before and After Tariff Liberalization Under a Stochastic Scenario

Country(s)	τ_s (Tariffs)	Stochastic Baseline Scenario Mean	Stochastic Baseline Scenario Standard-Deviation	Stochastic Policy Scenario Mean	Stochastic Policy Scenario Standard-Deviation
Bangladesh	4.54	0.7	6.0	0.0	5.7
Indonesia	1.47	0.9	7.7	−4.0	6.3
Philippines	6.19	1.1	6.1	−12.1	4.7
Thailand	20.42	1.1	4.4	25.0	5.7
Vietnam	2.76	2.6	7.2	6.9	5.8
Brazil	0.14	1.1	4.9	1.6	3.9
Chile	6.98	1.0	9.4	0.7	9.2
Colombia	12.77	0.5	3.8	−2.8	3.6
Mexico	23.94	0.9	8.6	−10.9	7.2
Peru	16.46	0.5	4.9	−5.1	4.4
Venezuela	12.10	1.2	9.7	−1.1	9.4
Malawi	0.08	4.0	20.6	3.1	19.9
Mozambique	2.11	2.8	16.8	−1.5	16.0
Uganda	0.72	2.4	14.5	0.8	14.1
Zambia	2.90	2.9	17.5	2.2	17.0
Poverty Regions' Average Tariff 11.39					
Average Tariff for other Regions 34.89					
World Average Tariff 30.65					

Source: Calculations using GTAP Database version 6 for tariffs and using Model Simulation Results for others

The average applied import tariffs are calculated as

$$\tau_s = \sum_i \left(\frac{\sum_r VIW_{irs}}{\sum_r \sum_i VIW_{irs}} \cdot \left[\sum_r \left(\frac{VIW_{irs}}{\sum_r VIW_{irs}} * \tau_{\text{irs}} \right) \right] \right)$$

where the Value of Imports (VIW_{irs}) at World prices by commodity*(i)*, source *(r)* and destination*(-s)*;and the tariff rates (τ_{irs}) come from GTAP version 6 database.

comparison of pre and post reform distributions of endogenous variables that "drive" the poverty headcount results. As indicated in equation (1), these are the consumption prices and factor earnings.

Distributions of Driver Variables

The comparison of the mean and standard deviations of driving factors – staple grains consumption prices (affecting the cost of living) and real after tax factor earnings (affecting income) – across the stochastic baseline and stochastic policy scenarios should provide insights into the results of formal test of the poverty headcount distributions under the same scenarios. If the moments of distributions for these variables differ little across the two scenarios, then results for poverty headcounts will also very likely not be distinguishable.

Tables 2 and 3 present the results for these driver variables – staple consumption prices and factor incomes respectively – for all 15 countries. For example the mean staple grains consumption price in Mexico increases by 0.9 percent under stochastic baseline while it falls by 10.9 percent under the stochastic policy scenario; so there is a difference of 11.9 percentage points between the two scenarios for Mexico. The same figure for Thailand is 25.0 – 1.1 = 23.9 percentage points (Table 2). For Mexico, most of the change is driven by the reduction in prices as a result of removing high import tariffs in the country. The increase in staples price in Thailand is driven by the increased price of rice owing to increase in rice export demand (Appendix II). The reforms seem to benefit *consumers* in Latin America; as the mean staple prices are lower (except for Brazil[13]) and no more volatile under the stochastic policy scenario as compared to the baseline scenario (Table 2). Also it is interesting to see that, while mean outcomes (especially for staple grains) show some difference, the standard deviations across the scenarios are very similar, this we suspect, is partly due to the omission of endogenous trade policy responses to world market price variability in this analysis. (This issue is explored in more detail below.)

A similar comparison of after-tax real factor earnings is offered for the focus countries (Table 3). The first panel in the table gives the percentage point differences in means while the bottom panel gives the same for standard deviations. A positive number indicates that the post liberalization mean or standard deviation for the factor endowment in a given country is higher than under the baseline (no liberalization) scenario. The changes in factor returns to land and agricultural capital are greater than those for other factors due to their sector specificity and more limited factor mobility respectively. Also, as with the results in Table 2, the changes in standard deviations are generally modest.

Small changes in the standard deviation compared to the mean suggest that the Kolmogorov-Smirnov (henceforth KS) two sample test[14] can be used as a formal test of difference in distributions of consumption prices and factor earnings. The KS test answers the question: are the observations under one scenario systematically larger or smaller than under the other scenario? Test results for staples consumption prices and factor earnings are provided in Appendix III. The main conclusion of the test is that, while some factors earnings are statistically different post liberalization, this finding is by no means universal across factors and countries. Given that strata are defined based on income specialization, it is therefore likely that the results will show within-country, across-stratum differences in the visibility of poverty headcounts. The next section

13. The deterministic results in Appendix II show the reason for increased post liberalization prices in Brazil on account of increased demand for coarse-grain exports from the country.

14. This test in comparison to other non-parametric tests performs better for cases where there is not much difference in variance (Baumgartner *et al.* 1998).

TABLE 3. Differences in Mean and Standard Deviations of Real After-Tax Factor earnings between Stochastic Policy and Stochastic Baseline Scenarios (percent changes)

	Bangladesh	Indonesia	Philippines	Thailand	Vietnam	Brazil	Chile	Colombia	Mexico	Peru	Venezuela	Malawi	Mozambique	Uganda	Zambia
Mean															
Land	−1.0	−2.5	−3.9	15.4	4.5	1.4	−1.7	−0.7	−2.1	−2.5	−0.7	−1.7	−1.4	−0.6	−1.3
Ag-Unskilled	0.0	−0.4	0.2	1.4	0.5	0.0	−0.1	0.2	0.4	0.0	0.0	−0.2	0.3	0.0	0.0
Ag-Skilled	0.0	−0.1	0.9	0.9	0.4	0.0	−0.1	0.2	0.5	0.0	0.0	−0.1	0.4	0.1	0.1
NonAg-Unskilled	0.2	0.7	1.9	−2.1	−0.2	0.0	0.1	0.3	0.8	0.4	0.1	0.0	0.5	0.2	0.2
NonAg-Skilled	0.2	0.8	2.1	−2.2	−0.1	0.0	0.1	0.3	0.8	0.4	0.1	0.0	0.5	0.2	0.2
Wage-Unskilled	0.2	0.5	1.2	−1.5	−0.1	0.0	0.1	0.3	0.8	0.3	0.1	−0.1	0.4	0.1	0.1
Wage-Skilled	0.2	0.8	2.1	−2.2	−0.1	0.0	0.1	0.3	0.8	0.4	0.1	0.0	0.5	0.2	0.2
Ag-Capital	−1.0	−2.5	−3.9	15.4	4.5	1.4	−1.7	−0.7	−0.6	−2.6	−0.7	−1.7	−1.4	−0.6	−1.4
Nag-Capital	0.2	0.8	2.1	−2.4	−0.1	−0.1	0.1	0.4	0.9	0.6	0.1	0.0	0.5	0.2	0.2
Transfers	0.1	0.5	1.2	−1.0	0.2	0.0	0.0	0.3	0.8	0.3	0.1	−0.3	0.3	0.0	0.1
Standard Deviation															
Land	−0.7	−0.7	−1.2	1.8	−2.4	0.0	−0.1	0.1	−0.2	−0.8	−0.1	0.2	−0.3	−0.5	−0.3
Ag-Unskilled	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	−0.1	0.0	0.6	0.1	0.0	0.1
Ag-Skilled	−0.1	0.0	−0.3	0.1	0.0	0.0	0.0	0.0	0.0	−0.1	0.0	0.5	0.0	−0.1	0.2
NonAg-Unskilled	−0.1	−0.2	−0.5	0.0	−0.3	0.0	0.0	0.0	0.0	−0.1	0.0	0.4	0.0	−0.1	0.1
NonAg-Skilled	−0.2	−0.2	−0.6	0.0	−0.3	0.0	0.0	0.0	0.0	−0.1	0.0	0.4	0.0	−0.1	0.1
Wage-Unskilled	−0.1	−0.1	−0.4	0.0	−0.2	0.0	0.0	0.0	0.0	−0.1	0.0	0.5	0.0	0.0	0.1
Wage-Skilled	−0.2	−0.2	−0.6	0.0	−0.3	0.0	0.0	0.0	0.0	−0.1	0.0	0.4	0.0	−0.1	0.1
Ag-Capital	−0.7	−0.7	−1.2	1.8	−2.4	0.0	−0.1	0.1	0.0	−0.8	−0.1	0.2	−0.3	−0.5	−0.3
Nag-Capital	−0.1	−0.2	−0.4	0.0	−0.3	0.0	0.0	0.0	0.0	−0.1	0.0	0.4	0.0	−0.1	0.0
Transfers	−0.1	−0.1	−0.2	−0.1	−0.1	0.0	0.0	0.0	0.0	−0.1	0.0	0.1	0.0	0.0	0.0

Source: Authors' calculations Using Model Simulation Results

TABLE 4. K-S Test Statistics, P-Values and Moments of Distributions Across the Baseline and Policy Scenarios for Poverty Headcount Changes

			Stochastic Baseline Scenario (in thousands)		Trade Liberalization in Stochastic Framework (in thousands)	
	Calculated KS Test Statistic	P-value	Mean	Standard deviation	Mean	Standard deviation
Bangladesh	0.18	0.84	83	598	14	553
Indonesia	0.41	0.04	10	41	25	31
Philippines	0.27	0.39	−11	277	98	262
Thailand	0.18	0.63	0	7	1	8
Vietnam	0.14	0.87	3	13	11	0
Brazil	0.14	0.92	21	113	27	106
Chile	0.36	0.06	0	3	2	3
Colombia	0.32	0.20	3	16	−6	16
Mexico	0.64	0.00	11	104	−128	96
Peru	0.36	0.06	3	24	−9	20
Venezuela	0.27	0.39	4	24	−1	23
Malawi	0.32	0.20	0	17	8	26
Mozambique	0.23	0.57	7	46	−6	48
Uganda	0.27	0.39	−12	14	−5	9
Zambia	0.14	0.92	7	59	2	62

Source: Authors' calculations using Model Simulation Results

The negative numbers under the mean columns are to be interpreted as a reduction in poverty headcount.

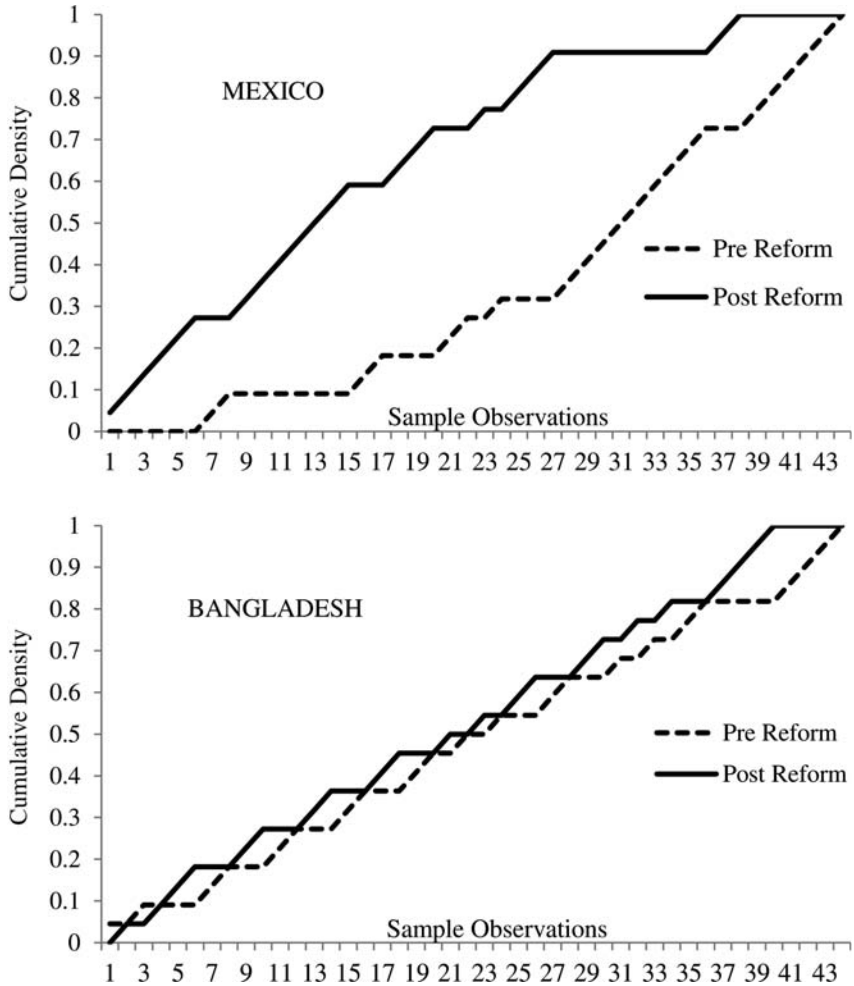
offers a formal test of differences between poverty headcount distributions at both the country and stratum levels.

Distribution of Poverty Headcounts

The KS test is implemented to formally compare the two distributions of poverty headcounts, resulting from stochastic baseline and stochastic policy reform scenarios. The null hypothesis is that the two distributions are not statistically different and are therefore hard to tell apart. Calculated KS test statistic values, along with the associated P-values are reported for all the focus countries (Table 4). The table shows that poverty headcount changes following trade liberalization are statistically perceptible at a 10 percent level of significance, in just four countries: Indonesia, Chile, Peru and Mexico.

Figure 1 shows what the results look like graphically for two cases – Bangladesh and Mexico – one where the two distributions are not statistically distinct and the other where they are clearly differentiated. The lines in the figure are the sample cumulative density functions (CDFs) for poverty headcount changes in the two countries under alternative scenarios. The sample

FIGURE 1. Empirical Cumulative Distributions of Poverty Headcount Changes in Mexico and Bangladesh



Source: Model simulation results

observations refer to the pooled samples generated by the repeated model simulations under the two stochastic scenarios (see Appendix III for technical details). The maximum vertical distance between the two lines is the KS test statistic. For Bangladesh, these sample CDFs lie very close together while they lie farther apart and do not overlap for Mexico. The samples in question are those generated under the stochastic baseline and under stochastic trade liberalization. The figure brings out the nature of our results very clearly – the effects are visibly distinct in one case while not in the other. This point is further underscored via a set of diagnostic plots reported for all the sample countries in Appendix IV.

The results of the KS test of the invisibility hypothesis for all seven strata in each of the 15 focus countries are provided in Table 5. At the 10 percent level of significance (p-value less than 0.1), for only 30 of the 105 country- stratum pairs the results turn out to be statistically distinct. Note that in Indonesia the headcount changes are statistically visible only in the agricultural stratum; however because this stratum has a 42 percent share in the national poverty headcount (Appendix Table A2), its statistical significance carries over to the overall national-level invisibility hypothesis test results. Conversely, while poverty headcount changes are statistically significant for all but the rural and urban diverse strata in Philippines, the changes at the national level are not significant. This stems from the fact that the two diversified strata comprise over 70 percent of Philippines's poverty population (23 percent for urban diverse and 49 percent in rural diverse, as shown in Appendix Table A2). Two other cases that stand out in these results are Chile and Thailand. For Chile, while the national level impacts of trade reform are visible, only the agricultural stratum is statistically significant and it makes up only 26 percent (Appendix Table A2) of the country's poverty headcount. In Thailand, while all strata show significantly perceptible poverty headcount results, the same does not hold for the national level results due to the fact that the agricultural headcount reductions are offset by the urban increases. The lower panel of Table 5 sheds further light on this conundrum. For Thailand while the stratum headcounts scenarios differ significantly, the total headcount does not vary much between the two scenarios. The opposite is true for Chile, where poverty rises for most strata.

The broad findings are that short-run poverty changes resulting from liberalizing staples sectors are large enough to be discernable in four of the fifteen focus countries: Peru, Mexico Chile and Indonesia. The P-values for the KS test (Table 4) suggest that the impacts are most likely to be visible in Latin America and least likely to be so in Africa and Asia. The visibility of impacts depends on initial level of tariffs, degree of inherent volatility and magnitude of policy shocks. Mexican poverty reduction benefits from reduction in a relatively high staple grains import tariff (Table 2), whereas most of the Sub-Saharan African countries fail to get visible impacts due to their highly volatile domestic markets. Also, even though the results are not statistically visible at the country level for some cases, a look at a more disaggregated (stratum) level can reveal a different result. In a cross country comparison, while the national level results for Peru and Malawi look very different (Table 4); the change in agricultural stratum poverty in both countries is equally visible (Table 5). Similarly poverty changes in rural diverse stratum in Peru and Venezuela are invisible to the same degree (Table 5).

What If Trade Policy Changes Are Endogenous?

So far the analysis assumed that trade policy changes are exogenous and are not subject to short term manipulation. However as seen in recent years,

TABLE 5. P-Values for KS test of "*Invisibility Hypothesis*" at Stratum Level

	Agriculturally self-employed	Non-agriculturally self-employed	Rural Labor	Urban Labor	Transfer Income	Rural Diverse	Urban Diverse
Bangladesh	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Indonesia	0.01	0.20	0.25	0.25	0.39	0.87	0.63
Philippines	0.06	0.01	0.00	0.00	0.01	0.39	0.84
Thailand	0.00	0.00	0.00	0.00	0.00	0.02	0.04
Vietnam	0.001	0.84	1	1	0.63	0.84	0.04
Brazil	0.25	0.63	0.63	0.63	0.92	1	1
Chile	0.06	0.84	0.84	0.84	0.92	0.57	0.20
Colombia	0.06	0.22	0.20	0.20	0.20	0.20	0.20
Mexico	0.00	0.001	0.001	0.001	0.00	0.00	0.00
Peru	0.00	0.04	0.04	0.04	0.02	0.39	0.22
Venezuela	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Malawi	0.01	0.84	0.84	0.84	0.63	0.25	0.25
Mozambique	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Uganda	0.84	0.92	0.92	0.92	1	0.57	0.84
Zambia	0.87	0.92	0.92	0.92	0.92	0.92	0.92

Mean Poverty Headcount Changes across Scenarios and Strata (in '000)

	Scenario	Agriculturally self-employed	Non-agriculturally self-employed	Rural Labor	Urban Labor	Transfer Income	Rural Diverse	Urban Diverse	Total
Thailand	Reform	−5.1	1.3	2.8	0.2	4.3	−3.3	0.5	0.7
	No-reform	−0.3	0.1	0.2	0.0	0.3	−0.1	0.0	0.2
Chile	Reform	1.1	0.0	0.0	0.0	0.1	0.2	0.3	1.7
	No-reform	−0.2	0.0	0.0	0.1	0.2	0.0	0.0	0.1

Source: Authors' calculations using Model Simulation Results exporters and importers frequently resort to imposing export taxes and lowering import tariffs respectively, when world market prices rise sharply. Martin and Anderson (2012) argue that such policy actions contributed as much as a third of observed world price changes in the recent commodity price boom. Because the analysis thus far has ignored this possibility, it has potentially understated the benefits of altogether eliminating trade barriers for staple grains. The logic behind this argument is as follows. If Martin and Anderson are correct, and endogenously varying trade policies serve to amplify world price changes in the face of production shortfalls, then fully eliminating such policies should have a stabilizing influence on world prices. Furthermore, by reducing price variations, trade liberalization would be more likely to result in statistically discernable changes in poverty.

To explore this possibility, a robustness check is undertaken to compare the liberalization scenario to a new baseline scenario wherein export taxes and import tariffs respond endogenously to changes in commodities' export and import prices faced by a country. Lacking information on country-specific approaches to insulation and seeking to obtain an outer bound on our results, the results reported in this section pertain to the case where all countries seek to insulate their domestic markets from world price changes. This is done by manipulating border taxes to eliminate half of the deviation in border prices (relative to a global trade price index).[15] The results indicate that when all exporters and importers resort to such responses, world prices under the new baseline scenario increase by a factor of about two in comparison to the case when trade shocks are treated as exogenous. The standard deviation of international prices as well becomes twice as large; while not much is achieved on moderating domestic price movements, due to the greater international price volatility under the new baseline. In effect, when every country attempts to export its price variability, no country is able to stabilize its prices. This confirms the theoretical arguments presented by Martin and Anderson. Turning to the invisibility hypothesis; because domestic commodity and factor prices are the driving forces behind poverty headcount results, and they aren't affected greatly since the attempt to insulate is frustrated by greater world price volatility, one should not expect to see a big difference in the poverty results. Applying the KS test for the new regional headcount numbers, still leads to the invisibility hypothesis being rejected for the same four countries (Appendix Table A11); however, at the stratum level results do look somewhat different, with 5 more cases gaining significance (Appendix Table A12) in the presence of endogenous policies.

15. This value of 0.5 is not entirely random. Anderson and Nelgen (2010) provide estimates suggesting that only about half the movement in international prices is transmitted to domestic markets for the period spanning 1985-2007.

III. Conclusions

This study developed a framework to address the question about the relative size of trade policy induced poverty changes versus those induced by the inherent volatility in agricultural markets; this is a different question and should not be confused with the more familiar question of quantifying the poverty impacts of trade reforms. Even if trade reforms are economically relevant, it is entirely possible that trade policy reform induced changes in a country's poverty headcounts are large but invisible, due to the high degree of commodity market volatility, as seen in the case of the Philippines. Conversely, modest impacts from grains liberalization may be visible in markets like Chile. The differences in visibility results can be explained by the differences in initial level of tariffs, degree of inherent volatility and magnitude of policy shocks faced by a country.

Overall, at the national level, the short-run poverty impacts of full liberalization of grains' trade are statistically distinguishable in less than a quarter of our sample countries. Even though policies do affect poverty headcounts in the remaining 11 countries, the changes are masked by the price changes due to the volatile nature of grains markets. So, broadly speaking, this study fails to reject the hypothesis that the short run national poverty impacts of trade policies are in fact invisible in the presence of volatile commodity markets. It is therefore important for the advocates of agricultural trade liberalization to not overstate the near term impacts.

However, the results vary by stratum within countries, and the results for individual strata can be very different from the country level results. An extreme example is given by the case of Thailand where, even though poverty headcounts are visible at the stratum level, the invisibility hypothesis at the national level cannot be rejected. Also, not surprisingly, the visibility is highest for poverty changes amongst the agriculturally self-employed (Table 5). Results for this stratum are found to be significant for 9 of the 15 sample countries. Therefore, the answer to the invisibility question depends on the level (national or stratum) at which the question is asked. Certainly the impacts of trade reforms on agriculture-specialized households in countries with relatively stable commodity markets are quite likely to be visible.

Appendices

Appendices can be found on Internet at:https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3386.

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