Assessing the distributional impact of technical change in livestock and grains production in developing countries

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Abstract

This paper outlines a general framework for analysing the distributional impact of commodity and factor price changes on the welfare of disaggregate households. The impact may be decomposed into an average effect and the departures from that average. The latter departures may be attributed to interactions between the commodity price changes and differences in consumption shares, on the one hand, and interactions between factor price changes and differences in factor earnings shares, on the other hand. Differences in consumption shares across households are estimated at the quintile level, using the International Comparisons Project (ICP) database in conjunction with the Deninger–Squire database on income distribution. Estimated differences in factor income shares are obtained by combining information on total factor earnings, with observations on income by quintile, and initial estimates of the factor earnings pattern by quintile. Regional price impacts of technological change are estimated using the Global Trade Analysis Project (GTAP) model of global trade. We find that, in the case of Korea, Sri Lanka and Zambia, technological change in grains benefits the poorest house- holds relatively more than a comparable improvement in livestock productivity. The opposite is true in Thailand. With the exception of the Zambia livestock sector, technical progress in either livestock or grains benefits poorer households relatively more than their wealthier counterparts. While this stems primarily from their larger food consumption share, improvements in unskilled wages also play a role.

JEL classification codes: O1, O3, Q1

Keywords: Income distribution, technological change, agriculture

1 Introduction

Two characteristics distinguish the world's poor. First, they are disproportionately rural and thereby reliant for their livelihood on agriculture and related industries. Second, they spend a disproportionate share of income on food products. Therefore, technological improvements that simultaneously raise productivity and incomes in rural areas and lower food prices would seem to offer great scope for reducing the incidence of poverty. The objective of this paper is to quantify the distributional consequences of technological progress in grains and livestock production.

The distributional consequences of technological change in agriculture have been studied previously by a number of authors. Scobie and Posada (1978) estimated the impact on household income distribution of a rice research programme in Colombia. Their approach is partial equilibrium in nature and abstracts from impacts on factor markets. Coxhead and Warr (1995) highlight the critical role of factor markets in determining the poverty impact of technological change in the Philippines. They find that two-thirds of the poverty reduction is transmitted through the factor markets. Their approach is a general equilibrium one and explicitly accounts for the earnings profile of households across the income distribution.

In this paper, we introduce an approach to assessing the differential impact of technological progress, both across sectors and across countries. Our approach is general equilibrium in nature since we explicitly account for both factor and commodity market effects. However, it differs from the work of Coxhead and Warr (1991); Warr and Coxhead (1993); Coxhead and Warr (1995), in that the distributional consequences of the technical change are assessed *ex post facto*. This permits us to capitalise on three key international databases in our analysis, namely: the International Comparisons Project (ICP) data on consumption, the Deninger and Squire data on income distribution, and the GTAP database on global trade and production. The approach that we develop can be applied across a wide range of countries, and provides a useful complement to the detailed country case-study approach offered by Coxhead and Warr.

We begin with a simple framework in which the incidence of technical change on different income groups is divided into three components: an average per capita effect, common across all groups; a differential effect due to changing consumer prices; and a differential effect due to changes in returns to factors of production supplied by households. The key to this approach lies in identifying differences in household budget and income shares. While this can be done via survey methods, such surveys are expensive, do not cover the entire population, and are conducted at infrequent intervals. This paper proposes an alternative approach to estimation of the incidence of technological change when such surveys are either not available, or are out-of-date.

On the demand side, we utilise a new model of consumer demand—An Implicit, Directly Additive Demand System—nicknamed AIDADS. AIDADS has been shown to be a valuable tool for modelling consumer demands across the income spectrum (Rimmer and Powell 1996). Cranfield et al. (1998) used AIDADS to show that in the poorest countries, the share of expenditure allocated to livestock purchases increases with per capita expenditure growth, while grains' share declines. Later, Cranfield et al. (1999) showed that the AIDADS model is preferred to other models when predicting changes in demand for food. However, when estimated with aggregate (national-level) data, AIDADS can only provide information needed to assess the per capita impact of price changes. To address this limitation, Cranfield (1999) developed a framework whereby aggregate data are supplemented with summary information on the distribution of income to estimate demand systems that are disaggregated by income class. Such disaggregation is extremely valuable in assessing the impact of agricultural productivity gains on the welfare of the poorest households.

Of course, the disaggregate demand systems estimated within this framework only reflect the consumption-side impacts of price changes engendered by technological progress. The differential impact on household earnings depends on factor earnings differentials across income groups. Here, we have less to build on. Therefore, we propose a simple, matrix-balancing approach that can accommodate detailed survey data, if available. In this paper, we show that simple information on the distribution of factor income by quintile, and the distribution of aggregate income by factor of production, combine to impose some relatively tight bounds on the factor incidence effects of technological change.

Price changes are determined using the GTAP model. GTAP is a model of world production, consumption, and trade of agricultural and non-agricultural commodities. It has been used widely to analyse the impact of changes in production, consumption and trade policy (Hertel 1997). It has also been used to examine the international incidence of technological change (Frisvold 1997; Ehui and Tsigas 1999) and the impact of technological spill-overs related to trade (van Meijl and van Tongeren 1999). However, it has not yet been used to analyse the intra-regional, domestic distributional consequences of such changes. Hence the contribution of this paper.

2 Analytical framework

Deaton and Muellbauer (1980) discussed the role of cost-of-living indices in assessing the impact of policy changes on household welfare. In particular, one may use compensated variation (CV) or equivalent variation (EV) to assess the impact of price changes, but with different reference levels of utility. Since each money metric measure of utility (i.e. CV and EV) is based on the consumer's expenditure function, results from empirical demand analysis prove useful in assessing the welfare effects of policy changes. Provided the estimated demand system satisfies the integrability conditions of consumer demand, the corresponding estimates can be used to calculate cost-of-living indices. In fact, Deaton and Muellbauer (1980, pp. 176–177) provided an example where pooled time-series and cross-section data were used to generate cost-of-living indices for households with differing numbers of children and income levels, and for households across time periods. However, the extent to which one can compute cost-of-living indices depends crucially on the availability of data. Nevertheless, the spirit of their example is important—cost-of-living indices allow one to assess the distributional consequences of changes in economic factors affecting welfare.

For purposes of this paper, we will focus on the impact of technological change on population quintiles, rather than individual households. The first quintile contains the poorest 20% of the population, while the last (fifth) quintile encompasses the wealthiest 20% of the population. For each quintile, we can think of a representative household that maximises utility subject to exogenous prices and income, whereby the latter is determined by the inner product of a vector of fixed factor supplies from that household (i.e. land, labour and capital) and exogenous returns to these factors. Letting: Q_n denote quantity demanded, P_n price and Y income, we have:

$$\max U(Q_1, \ldots, Q_N)$$

$$\text{(1)} \quad st. \sum_{n=1}^{N} P_n * Q_n = Y$$

It can be shown (Appendix 1), that the CV for quintile i, of a given pattern of income and price changes, expressed as a percentage of initial expenditure (income), may be approximated by:

$$\text{(2)} \quad cv^i = -\left[y^i - \sum_n \theta^i_n p_n \right]$$

Where q^i_n is quintile i's budget share for good n, p_n is the percentage change in the price of that good and y^i is the percentage change in income received by quintile *i*. If the share-weighted average for consumer prices rises, relative to income, then compensation will be required ($cv^i > 0$) in order to hold this quintile at its initial level of utility.[1]

1. While this CV measure is distinct from the EV measure commonly used in the welfare analysis, and it is only an approximation, we will see below that the CV approximation and the exactly computed EV yield very similar findings. Since equation 2 facilitates economic analysis of the consequences of technical change, we will work with that expression here.

From the point of view of incidence analysis, what we are most interested in is the 'differential impact' across quintiles. Therefore, it is useful to normalise the consumer price and income changes by comparing them to the averages for the economy as a whole (*cpi* and *y*, respectively). This gives the following:

$$\text{(3)} \quad -cv^i = (y - cpi) + (y^i - y) - \left[\sum_n \theta^i_n p_n - cpi \right]$$

In equation 3, the first term captures the average per capita percentage increase in real income (negative *cv*) in the region in question. The second term describes the percentage change in quintile income, relative to the per capita average. The third term measures the change in the quintile-specific consumer price index, relative to the average for the economy as a whole.

Further insight can be obtained by substituting in the following equations describing the income and consumer price index changes in terms of underlying prices:

$$(4) \quad cpi = \Sigma \lambda_n p_n$$

$$(5) \quad y^i = \sum_m \Omega^i_m w_m$$

$$(6) \quad y = \sum_m \Pi_m w_m$$

Here l_n is the share of consumer good *n* in the average per capita household's budget; W^i_m is the share of primary factor *m* in quintile *i*'s income P_m is primary factor *m*'s share in the per capita household's income; and w_m is the percentage change in the market return to primary factor *m*.

Substituting equations 4–6 into equation 3 yields:

$$(7) \quad -cv^i = (y - cpi) + \sum_m (\Omega^i_m - \Pi_m) w_m - \sum_n (\Theta^i_n - \lambda_n) p_n$$

Equation 7 makes it clear that departures from the average change in real income in a country (the first term on the left-hand side of equation 7) can be accounted for by interactions between price changes and differences in expenditure and income shares. This decomposition greatly facilitates identification of the underlying sources of differential welfare impacts by quintile. Next we describe how we estimate the quintile-specific expenditure shares (Section 3), the quintile-specific income shares (Section 4), and the price changes (Section 5).

3 Analysing patterns of household consumption by income class

3.1 General approach

The most obvious method for specifying the shares in equation 7 is to simply observe them. Such data from national consumer surveys are indeed available for many countries (e.g. the US Bureau of Labor Statistics Consumer Expenditure Survey and the UK Office for National Statistics Family Expenditure Survey). However, in most countries national surveys of this sort are either not available or not up-to-date. A much more common state of affairs is to have observations on the average per capita budget shares and the distribution of expenditure by quintile, while lacking any direct observations on the quintile-specific pattern of expenditure by product. In such cases, the welfare analysis suggested by equation 7 is not feasible. Some alternative must be found and it would be attractive if this alternative offered a vehicle for updating the expenditure shares to the current period.

In this paper, we draw on recent work by Cranfield (1999) who estimated the parameters of a complete demand system while simultaneously utilising data on the distribution of expenditure by quintile, to permit recovery of the unobservable distribution of expenditure for each quintile. The approach requires data typically used in demand system estimation (i.e. prices, per capita quantities and per capita expenditure), in addition to summary measures of the distribution of expenditure (or income), such as variance, skewness, kurtosis, or quintiles and the relevant range of expenditure in each observation. Rather than estimating a model that predicts a budget share for each good on a per capita basis in each observation, the framework approximates the distribution of expenditure, estimates demand system parameters consistent with the demand and expenditure data (including the distribution information), and predicted budget shares for each good *across expenditure levels within each observation*. An added benefit is that, with a complete demand system in hand, expenditure shares for more recent years can be predicted, based on information about changes in per capita income and prices.

We use consumption, price and expenditure data from a subset of the 1985 International Comparisons Project (ICP) data set for the demand system portion of the model. Quintile data are used as summary measures of the expenditure distribution, and are obtained from the Deninger and Squire (1996) database and the World Bank's (1992, 1993) reports. Given these quintile data, we approximate a finer distribution of expenditure across 15 expenditure levels for each observation in the ICP data set. These 15 expenditure levels are equally allocated across the 5 quintiles (i.e. there are 3 expenditure levels within each quintile). Note that the recovered expenditure distribution aggregates back to the per capita expenditure levels in the ICP data, and the observed quintile data.

For brevity, the data and sources are described in Appendix 2. Our sample contains 53 countries from the ICP data set for which corresponding quintile data were available. The ICP consumption and price data are combined up to five goods. The broad categories of goods are livestock products, other food products, other non-durable goods, durable goods and services.

3.2 Choice of functional form

Since we are using the demand system to estimate consumer expenditure at different income levels, both within and across countries, it is vital that this demand system be sufficiently flexible to capture the wide range of consumer behaviour that might arise over the global income spectrum. In this study, we adopt Rimmer and Powell's (1992a, 1992b, 1996) AIDADS (An Implicitly Directly Additive Demand System), specifically for capturing expenditure patterns across the development spectrum. This may be viewed as a generalisation of the popular, but restrictive, Linear Expenditure System (LES). Unlike the LES, AIDADS allows for non-linear Engel responses, while maintaining an economical consideration of consumer preferences.

The following equation gives the budget share form of AIDADS:

$$(8) \quad w_n = \frac{p_n \gamma_n}{y} + \frac{\alpha_n + \beta_n \exp(u)}{1+\exp(u)} \left[1 - \frac{p'\gamma}{y} \right] \forall n$$

Where w_n is the budget share of good n, a_n, y_n and b_n are unknown parameters, u represents utility, and other parameters have the definition given earlier. The following parametric restrictions are used to ensure well-behaved demands: O£ a_n, b_n £ 1 for all n, and $\sum_{n=1}^{N} \alpha_n = \sum_{n=1}^{N} \beta_n$ =1. If a_n =b_n for all goods, then AIDADS simplifies to the LES. By replacing the values of b_n in the LES with more general terms, which are functions of a value that varies with real expenditure level (in this case utility), Rimmer and Powell (1996) allowed for marginal budget shares that vary across expenditure levels in a very general manner. Moreover, the budget shares from AIDADS also vary non-linearly across expenditure. This last point is important in the context of predicting the pattern of demand for food products across expenditure levels.

3.3 Estimated consumption relationships

Table 1 reports estimates of the AIDADS parameters for this study. For livestock, grains and other food, the estimate of a_i is greater than the estimate of b_i. Given the AIDADS structure, these estimates also represent upper and lower limits for the budget shares. For modest expenditure levels, livestock's budget share is about 0.14. However, as expenditure grows, livestock's budget share approaches 0.05. Upper and lower asymptotes for the grains products budget share are 0.11 and 0, respectively. The upper and lower bounds for the other food's budget share are 0.31 and 0, respectively. The lower bound of 0 for grains and other food may seem troubling as it implies that as expenditure grows without bound, expenditure on other food decreases to 0. Recall, however, that this is an asymptotic result and so does not imply that the budget share for other food ever actually reaches 0. More importantly, the estimate of g_n is zero for livestock and other food, but positive for grains. Thus, an individual with expenditure equal to subsistence consumption (i.e. where $y = \sum_{n=1}^{5} p_n \gamma_n$) is predicted to consume grain, but not livestock or other food. As expenditure grows, the subsistence household will begin to consume livestock and other food products. Consumption shares for these goods peak and then decline towards their minimum values.

Table 1. *An Implicitly Directly Additive Demand System (AIDADS) parameter estimates.*

	Grains	Livestock	Other food	Non-durables	Durables	Services
a	0.1135	0.1383	0.3079	0.2805	0.0529	0.1069
b	0.0000	0.0494	0.0000	0.3562	0.2483	0.3461
g	14.2859	0.0000	0.0000	10.0090	6.5971	14.7321

Figures 1, 2 and 3, plot the budget shares for livestock, grains and other foods, respectively, across 15 household income levels (3 levels within each quintile), in a selection of 4 focus countries (Zambia, Sri Lanka, Thailand and Korea). These data provide some intuition regarding the pattern of response that will be observed within countries, given the AIDADS parameter estimates and recovered expenditure distribution. The countries, namely Zambia, Sri Lanka, Thailand and Korea, were chosen to offer a spectrum of responses across countries with different per capita expenditure distributions.[2] Figure 1 shows that the range of livestock budget shares differs across countries. For example, over the relevant range of expenditure classes in Zambia, a hump shape is present in the budget share path. This means that as we move from low- to high-income households, the importance of livestock in the consumption bundle first increases, reaches a maximum and then declines; a more modest hump shape is observed for Sri Lanka. In contrast, the budget share paths for livestock in Korea and Thailand decline over the relevant range of expenditure, reflecting higher per capita incomes in these countries. Figure 2 shows that, in all four countries, the predicted budget shares for grain decline over the relevant range of expenditure classes. Of particular note is the dramatic reduction in grain budget share in Zambia, as one moves from the low- to high-income groups. In contrast, reductions in other countries are nearly linear in the log of expenditure. Finally, budget shares for other food (Figure 3) offer a similar pattern to those for livestock products.

2. The fitted values refer to 1995, the base year for our analysis below. They have been updated from 1985 (the year of the ICP data) in the following manner. It is assumed that relative prices remain constant, but that expenditure levels for each quintile increase by the percentage change in their respective country's real per capita gross domestic product (GDP) from 1985 to 1995. The percentage changes in the selected country's real per capita GDP (from 1985 to 1995) are as follows: Zambia –23%, Sri Lanka +34%, Thailand +114% and Korea +109%.

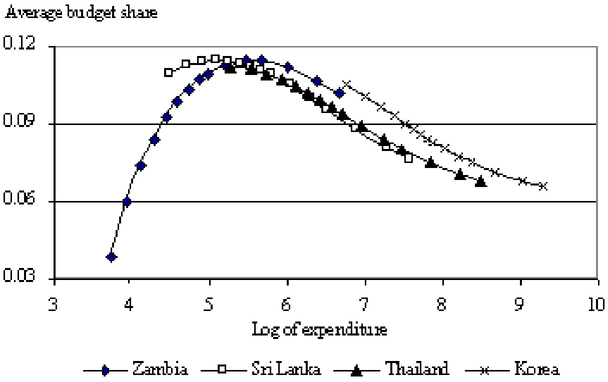

Figure 1. *Predicted average budget shares for livestock in 1995.*

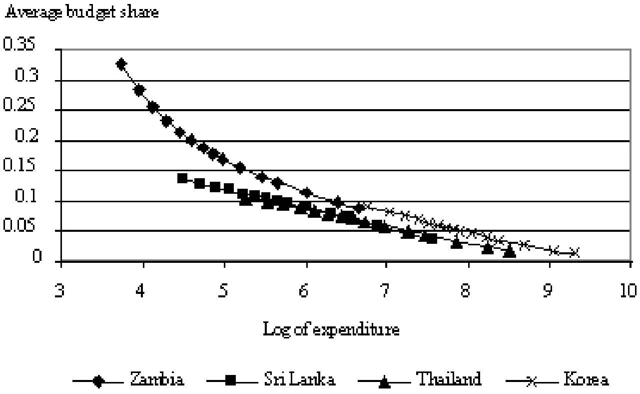

Figure 2. *Predicted average budget shares for grain in 1995.*

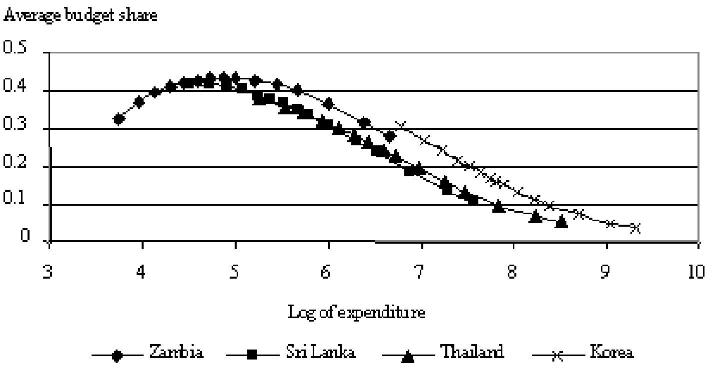

Figure 3. *Predicted average budget shares for other foods in 1995.*

Note that the plots in Figures 1, 2 and 3 reflect the range of expenditure embodied in the estimation framework. The levels of expenditure shown in the figures do not capture the full range of the expenditure in the respective countries, since the recovered expenditure distribution is fundamentally limited by the source data. Nevertheless, they serve as a useful approximation to the range over which consumption decisions may be made, and they clearly illustrate the importance of accounting for non-linear consumer responses to increased income.

Since the subsequent analysis will be conducted at the quintile level and will account for price changes in non-food products as well, the associated budget shares are repeated in Table 2 for each of the four focus regions. These shares composed q_n in equation 7 and they will be referred to when it comes to explaining results in Section 6 below.

Table 2. *Representative household expenditure shares on consumer goods.*

Quintile	Grains	Livestock	Other food	Non-durables	Durables	Services
South Korea						
1	0.085	0.106	0.202	0.303	0.116	0.186
2	0.060	0.092	0.149	0.318	0.152	0.229
3	0.054	0.088	0.135	0.322	0.161	0.240
4	0.044	0.081	0.110	0.328	0.177	0.260
5	0.024	0.067	0.062	0.341	0.209	0.298
Thailand						
1	0.101	0.115	0.240	0.295	0.095	0.155
2	0.084	0.109	0.212	0.303	0.113	0.179
3	0.073	0.102	0.186	0.310	0.130	0.200
4	0.058	0.092	0.151	0.319	0.152	0.228
5	0.030	0.072	0.079	0.337	0.198	0.284
Sri Lanka						
1	0.131	0.112	0.241	0.295	0.085	0.136
2	0.112	0.115	0.241	0.296	0.089	0.146
3	0.101	0.113	0.231	0.299	0.098	0.158
4	0.089	0.109	0.212	0.304	0.111	0.176
5	0.056	0.089	0.141	0.321	0.158	0.234
Zambia						
1	0.244	0.063	0.139	0.269	0.116	0.169
2	0.192	0.090	0.199	0.275	0.095	0.149
3	0.165	0.103	0.225	0.279	0.087	0.142
4	0.143	0.111	0.239	0.282	0.084	0.141
5	0.105	0.113	0.229	0.294	0.098	0.161

4 Factor ownership

While data on household consumption by quintile are difficult to obtain, information on the share of factor earnings by quintile is even more challenging. In fact, there is no international data source reporting factor ownership by income class. von Braun and Pandya-Lorch (1991) offered a compilation of information on income sources for the rural poor, based on household surveys conducted in Latin America, Africa and Asia. Several important points stand out. First, even in rural areas, households' income sources are quite diversified. In half of the 13 surveys, non-agricultural income exceeded agricultural income. Overall, non-agriculture's share in total income ranged from 13% to 67%. Secondly, poor households are heavily dependent on income in the form of wages. For this reason it is important to trace factor earnings back to fundamental factor returns, including returns to land, capital, and skilled and unskilled wages.

In this study, we capitalise on the fact that we have both information on average income per quintile, as well as estimated economy-wide factor earnings. This places rather tight limits on the distribution of factor ownership by household. Specifically, we utilise the known data to specify row and column totals for the factor payments/quintile matrix. An initial allocation of factor payments by quintile is then proposed, using stylised facts based on household income surveys. Moreover, the RAS (row and column sum) technique is employed to ensure a pattern of payments emerges that is consistent with the control. Of course, if better information were made available on the profile of factor earnings by quintile, this could be utilised directly. Indeed this entire approach is designed to accommodate improved estimates, as they become available.

What are the so-called 'stylised facts' that we use to get started? First, we assume that all income classes own equal amounts of unskilled labour. Furthermore, we assume that initially all income classes are also endowed with land, but that ownership distribution is strongly skewed towards wealthy households. Only the upper income households (quintiles three through five) are assumed to own skilled labour and this ownership pattern is skewed towards wealthier households. Finally, some capital is provided to all households, except for the poorest quintile; the skewness of the distribution of ownership of this factor is the most pronounced of all. This initial distribution of factor ownership across quintiles for each factor is reported at the top of Table 3. For example, these data show that 5% of the land is attributed to the poorest quintile and 20% of the unskilled labour is owned by each quintile. For a given quintile, per capita income is obtained by multiplying total per capita income by the percentage of income accruing to a quintile and then multiplying by five. This is equivalent to multiplying the percentage of income accruing to a quintile by the economy-wide income, and then dividing by the number of individuals in the quintile to get a per capita income within the quintile.

Table 3. *Distribution of factor payments by quintile for the four focus countries.*

Quintile	Land	Unskilled labour	Skilled labour	Capital
	Each matrix before balancing			
1	0.050	0.200	0.000	0.000
2	0.100	0.200	0.000	0.050
3	0.200	0.200	0.100	0.150
4	0.200	0.200	0.300	0.200
5	0.450	0.200	0.600	0.600

South Korea				
1	0.049	0.185	0.000	0.000
2	0.143	0.270	0.000	0.074
3	0.197	0.185	0.104	0.153
4	0.201	0.189	0.319	0.208
5	0.409	0.171	0.577	0.565
Thailand				
1	0.050	0.201	0.000	0.000
2	0.111	0.222	0.000	0.055
3	0.166	0.166	0.082	0.123
4	0.204	0.204	0.302	0.202
5	0.469	0.208	0.617	0.620
Sri Lanka				
1	0.026	0.125	0.000	0.000
2	0.076	0.180	0.000	0.035
3	0.151	0.179	0.068	0.104
4	0.186	0.221	0.253	0.172
5	0.560	0.295	0.678	0.689
Zambia				
1	0.031	0.143	0.000	0.000
2	0.079	0.183	0.000	0.037
3	0.153	0.177	0.070	0.107
4	0.185	0.214	0.255	0.172
5	0.552	0.283	0.675	0.684

This information, combined with information on the relative shares of economy-wide income accruing to the individual factors, is inevitably inconsistent. In particular, if total economy-wide income is shared out across factors, then shared out across and summed to determine total income by quintile, the resulting estimated income by quintile would differ from the original quintile data. To get around this problem, the original share of each factor owned by the different quintiles is adjusted to obtain consistency with both the total income by quintile and the shares of total income by factor. Specifically, we use the RAS procedure (Schneider and Zenios 1990). The method proceeds by iteratively rescaling the rows and columns of the matrix until consistency is obtained.

The result of the matrix-balancing algorithm for each of the four countries is displayed in the lower four sections of Table 3. Note that the pattern of zeros and non-zeros is unaltered by the RAS procedure. Also note that the adjustments are relatively small. For example, in the case of Thailand, the largest absolute adjustment is for unskilled labour for the third quintile (0.034), and the largest percentage adjustment is for skilled labour for the third quintile (17.1%). Combining the factor payment distributions in Table 3 with a set of factor payment totals and dividing by quintile income gives us the income shares, W^{i}_{m} used in equation 7. Thus, all that remains to be explained is the manner in which the price changes are generated. This will be discussed in the next section.

5 Modelling the price effects of technical change in livestock and grains production

5.1 Overview of the framework

The framework outlined above for evaluating the impact of technical change on households, by income class, requires price changes for commodities as well as primary factors. There are many ways these price changes could be generated. The ideal approach involves imbedding the quintile-based demand systems from Section 3 and the factor payments matrix from Section 4 into a complete general equilibrium model for each economy in question, and using this to generate the requisite price changes. However, this represents a major model-building undertaking and defeats our purpose of having a tool that is flexible and amenable to widespread use. Therefore, we opt for a compromise in which an existing model, without income distributional detail, is used to generate the price changes.[3]

3. We are therefore assuming that any change in income distribution resulting from the technical change has a second-order effect on aggregate demands, and hence prices.

In this report, we use the GTAP model of global trade, production and consumption (Hertel 1997). This is a relatively standard, applied general equilibrium model in which products are differentiated by origin (the Armington assumption), firms operate under constant returns to scale and perfect competition is assumed. Consumer demands are modelled using the Constant Difference of Elasticities (CDE) functional form that has been calibrated to own-price and income elasticities of demand from the literature (McDougall et al. 1998).[4]

4. This introduces another inconsistency, since these elasticities differ from those implied by the demand system being used to evaluate the quintile impacts. Some progress has been made incorporating the AIDADS demand system directly into GTAP (Coyle et al. 1998; Yu 2000). However, bringing this into line with the quintile-based analysis will require a substantial research effort and is therefore a topic for future research.

As with any such framework, there are advantages and disadvantages associated with the choice of the GTAP model. On the positive side, because it is a global model, we are able to conduct comparable analyses across a wide range of countries.[5] Also, since it is a general equilibrium model, we can obtain the full vector of price changes required for our analysis. A final advantage is GTAP's detailed treatment of intermediate flows between the livestock and grains sectors, and other parts of the economy. However, there are also some significant disadvantages. First, because GTAP is a global model, it lacks many of the country-specific features that a more detailed, single region model could offer. Secondly, it is a comparative static model. Thus, there is no dynamic dimension to the incidence analysis. Future applications of the methodology developed in this paper should experiment with alternative models for generating price changes.

5. There are 45 regions in the version 4 GTAP database (McDougall et al. 1998).

5.2 Aggregation of database

The full version 4.0 GTAP database is very large, and data are therefore aggregated up to 11 commodities and 12 regions for purposes of the present analysis. (See Appendix 3 for a detailed listing of these commodities and regions.) The aggregated commodities are designed to facilitate analysis of technical change in grains and livestock production and include: grains, livestock, other agriculture, processed livestock products, processed food products, natural resources, beverages and tobacco, clothing and footwear, other manufactured products, housing and utilities, and other services. The trade and transport sector is the source of margin activities, which serve to bridge the gap between GTAP's producer prices and the ICP (International Comparisons Project) consumer prices (see below).

The regional aggregation employed here focuses on developing countries. Organization for Economic Co-operation and Development (OECD) countries are grouped together, while non-OECD countries are organised geographically, breaking out target countries where we choose to focus our analysis.[6] Following the discussion in Section 3, we focus particular attention on one country from East Asia (South Korea), one from South-East Asia (Thailand), one from South Asia (Sri Lanka) and one from southern Africa (Zambia).[7]

6. Note that the ICP and income distribution data sets used to estimate the AIDADS (An Implicitly Directly Additive Demand System) do not cover all GTAP regions.

7. In the version 4 GTAP database, individual country coverage in Africa is very limited. Therefore, the price changes for Zambia are based on the GTAP region denoted 'Rest of southern Africa (RSA)'—i.e. southern Africa, excluding the South Africa Customs Union.

5.3 Experimental design

Following Frisvold (1997) we model technical change in the livestock sector as Hicks-neutral, thereby augmenting all factors of production equally. In order to facilitate comparison across sectors, within a given country, we have normalised each technology shock so that it generates an aggregate cost savings of 5% for agriculture as a whole. Thus if livestock represents one-third of agricultural output, then the technical change shock is 5%, i.e. one-third of 15%. If livestock represents one-half of agricultural output, then the shock becomes 5%, i.e. one-half of 10% and so on. The livestock productivity shocks used for the four focus regions are as follows: South Korea = 32.74%, Thailand = 43.70%, Sri Lanka = 94.38% and Zambia = 29.51%. The grain productivity shocks are as follows: South Korea = 8.77%, Thailand = 10.71%, Sri Lanka = 18.97%, and Zambia = 21.34%. These shocks are administered separately, in four distinct simulations. In each of these simulations, we focus only on the impact in the country experiencing the technological improvement.

The other important decision in designing such a simulation experiment with the GTAP model is the choice of closure. Of particular interest here is the treatment of the factor markets. For simplicity, we have assumed a medium-run closure in which labour and capital are freely mobile across sectors. We also assume no change in aggregate employment. (Fixing the real wage and allowing employment levels to vary would be an obvious alternative closure.) Land is the only sector-specific asset and therefore we expect its returns to be quite volatile in the wake of technical change.

5.4 Price impacts

Price changes for primary factors and commodities (at producer prices) based on the GTAP simulations of a 5% cost reduction in agriculture are presented in Table 4. Looking first at the middle panel (headed ‘Enhanced livestock technology’) of the table, it is not surprising to see that technical progress in livestock leads to a decrease in the farm-price of livestock in each country. The largest decrease occurs in South Korea (–18.47%) while the smallest is in Sri Lanka (–9.51%). The magnitude of the decrease is a function of two things: the size of the supply shift and the farm-level demand elasticity (Appendix 4). The latter is smaller in higher income economies (e.g. South Korea), where consumer demand is more price-inelastic, so the price drop is larger. In every case, the aggregate, farm-level demand for livestock in each region is price-inelastic, so that improvements in livestock technology depress prices by a greater percentage than that by which quantities increase. Therefore revenues fall, as do returns to the specific factor—land (Frisvold 1997).

Table 4. *Price changes for commodities and primary factors based on GTAP (Global Trade Analysis Project) simulations.*

	Enhanced livestock technology				Enhanced grains technology			
	South Korea	Sri Lanka	Thailand	Zambia	South Korea	Sri Lanka	Thailand	Zambia
Primary factors								
Land	–5.55	–2.60	–0.92	–3.53	–12.7	–2.59	9.49	–2.1
Unskilled labour	0.34	1.78	0.76	0.77	0.37	1.01	0.55	0.51
Skilled labour	0.51	2.33	0.74	1.35	0.74	1.37	0.1	1.06
Capital	0.45	1.45	0.48	0.74	0.7	0.63	0.02	0.58
Margin-exclusive goods								
Grains	–2.17	0.43	0.04	–0.50	–19.61	–15.91	–9.68	–18.51
Livestock	–18.47	–9.51	–14.64	–17.84	–4.59	0.1	0.51	–1.28
Other food	–1.12	–0.13	0.10	–0.42	–3.5	–0.27	0.6	–0.47
Non-durables	–0.09	0.69	0.20	–0.21	–0.59	0.22	0.09	–0.2
Durables	0.20	0.36	0.18	0.09	0.27	0.18	0.04	0.07
Services	0.24	1.41	0.16	0.32	0.31	0.75	0.07	0.18
Margin services	0.22	1.42	0.19	0.43	0.27	0.77	0.11	0.23
Margin-inclusive goods								
Grains	–1.78	0.59	0.06	–0.35	–16.59	–13.34	–8.12	–15.65
Livestock	–13.19	–6.03	–10.38	–14.14	–3.14	0.32	0.39	–0.95
Other food	–0.73	0.23	0.13	–0.22	–2.42	–0.03	0.46	–0.30
Non-durables	0.01	0.93	0.20	0.00	–0.30	0.40	0.10	–0.06
Durables	0.21	0.71	0.18	0.20	0.27	0.38	0.06	0.12
Services	0.24	1.41	0.16	0.32	0.31	0.75	0.07	0.18

The four columns on the right-hand side of Table 4 (headed ‘Enhanced grains technology’) indicate the price effects of a 5% cost reduction in agriculture due to technical progress in the grains sector. In each case the price of grain drops substantially, with the largest decline occurring in South Korea (–19.61%) and the smallest in Thailand (–9.68%). Returns to the sector-specific factor, land, fall in every case except Thailand, which actually experiences an increase of 9.49%. This is because—in contrast to the other countries—the farm-level demand for grains in Thailand is quite elastic (–2.33). This responsiveness in demand is a direct consequence of the large share of crop production that is exported (37%) (Appendix 4).

Therefore, in the case of Thailand, improvements in technology depress prices by a smaller percentage than that by which quantities inrease, causing crop revenues to rise, thereby boosting returns to land.

To make use of the commodity price changes from GTAP, they must be adjusted to incorporate the marketing margins necessary to bring them up to the consumer prices used in the demand system estimation. To address this issue, a simple, Cobb-Douglas wholesale/retail/trade sector is introduced in the post-simulation analysis. This sector combines GTAP producer goods with ‘margin services’ to produce consumer price changes. We do not have data on the share of margin services embodied in consumer goods for these focus countries. Therefore, the following simple assumptions are adopted. For manufactured and processed products, the margin is equal to 50% of the producer price. For farm products that are consumed without further processing, the margin is 20% of the producer price. In the case of Thailand, for example, application of these assumptions results in the following shares of margins in the value of consumer goods: 0.17, 0.30, 0.29, 0.33 and 0.33 for grains, livestock, other food, non-durables and durables, respectively. The implied margin-inclusive commodity price changes for each country are given in the bottom section of Table 4. Note that the explicit treatment of margins in this analysis tends to dampen the consumer price changes substantially.

6 Distributional impacts

Table 5 reports the approximate compensating variation (CV), as a percentage of initial expenditure, associated with a 5% cost reduction in agriculture due to improved technology. This is computed using equation 7, based on the shares and price changes developed in Sections 3–5 above.[8] For technical progress in livestock, CV ranges from a low of 0.88% for quintile 5 in Sri Lanka to a high of 2.29% for quintile 4 in Zambia. Data indicate that every quintile of every country experiences welfare gain in the wake of technological progress. The benefits are not uniform across quintiles, however. In Korea, Sri Lanka, and Thailand poorer households tend to benefit relatively more than wealthier ones, with the lowest quintile benefiting most from technical progress in livestock. In Zambia, the situation is reversed. Here, quintile 1 shows the lowest gains, with the highest gains appearing in the wealthiest two quintiles.

8. The actual compensating variation (CV) and the equivalent variation associated with these price changes are reported alongside the approximated CV in Appendix 5. A comparison shows that the measures are very similar. We henceforth work with approximated CV since it is computed using equation 7 and therefore allows us to decompose the welfare change.

Table 5. *Negativity of approximate compensating variation (CV) as a percentage of initial expenditure for a 5% cost reduction in agriculture.*

Sector with technical change	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
South Korea					
Livestock	1.74	1.37	1.28	1.25	0.99
Grains	2.10	1.36	1.20	1.16	0.70
Sri Lanka					
Livestock	1.55	1.35	1.16	1.23	0.88
Grains	2.24	1.80	1.48	1.39	0.76
Thailand					
Livestock	1.72	1.52	1.38	1.29	1.04
Grains	1.68	1.36	1.14	0.87	0.57
Zambia					
Livestock	1.71	2.00	2.13	2.29	2.23
Grains	4.14	3.42	3.06	2.82	2.24

When technical progress occurs in grains production, CV ranges from a low of 0.57% for quintile 5 of Thailand to a high of 4.14% for quintile 1 of Zambia (Table 5). In each of the four countries the distribution of gains follows the same pattern, with poorer households benefiting relatively more than wealthier households. What accounts for the different welfare effects across quintiles? This question can be pursued by examination of Table 6. The per capita, or average, effect on households in each country (CV as a percentage of initial expenditure) is presented for each quintile. This corresponds to the first term in the right-hand side of equation 7. It is followed by rows referring to the contribution of commodity, factor price changes to the quintile-specific effects. These represent the products of individual share differences and prices, as captured in the second and third terms of equation 7. The contribution of any given term to the relative welfare of a quintile will be positive in four different circumstances. First, when the quintile in question exhibits an above-average budget share for a good whose price falls, this will offer a positive contribution to welfare. Secondly, when the quintile has an above-average income share from a factor whose price rises, it will also gain. Of course, below average consumption or income shares will also be beneficial when the prices move in the opposite direction. Recall that the price changes may be found in Table 4. The quintile deviations from the per capita household are reported in Table 7. Substituting these values into equation 7 gives the entries in Table 6. (See Appendix 6 for a comparable table for the case of technical change in grains.)

Table 6. *Decomposition of CV (compensating variation) in the case of technical progress in the livestock sector.*

Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	
South Korea					
Per capita	1.20	1.20	1.20	1.20	1.20
Grains	0.08	0.03	0.02	0.00	–0.03
Livestock	0.36	0.16	0.11	0.02	–0.16
Other food	0.07	0.03	0.02	0.00	–0.03
Non-agriculture	0.03	0.01	0.01	0.00	–0.01
Land	0.08	–0.01	–0.06	0.02	0.01
Unskilled labour	0.21	0.12	0.02	–0.01	–0.07
Skilled labour	–0.07	–0.07	–0.02	0.03	0.03
Capital	–0.21	–0.10	–0.01	–0.01	0.07
CV*	1.74	1.37	1.28	1.25	0.99
Sri Lanka					
Per capita	1.07	1.07	1.07	1.07	1.07
Grains	–0.03	–0.02	–0.01	–0.01	0.01
Livestock	0.08	0.10	0.08	0.05	–0.07
Other food	–0.02	–0.01	–0.01	–0.01	0.01
Non–agriculture	0.14	0.12	0.10	0.05	–0.08
Land	0.13	0.05	–0.04	0.02	–0.02
Unskilled labour	1.00	0.67	0.23	0.07	–0.30
Skilled labour	–0.25	–0.25	–0.12	0.07	0.07
Capital	–0.58	–0.36	–0.13	–0.08	0.18
CV	1.55	1.35	1.16	1.23	0.88
Thailand					
Per capita	1.21	1.21	1.21	1.21	1.21
Grains	0.00	0.00	0.00	0.00	0.00
Livestock	0.32	0.25	0.17	0.07	–0.14
Other food	–0.01	–0.01	–0.01	0.00	0.01
Non-agriculture	0.03	0.03	0.02	0.01	–0.01
Land	–0.01	–0.01	–0.01	0.00	0.01
Unskilled labour	0.56	0.23	0.04	0.00	–0.09
Skilled labour	–0.05	–0.05	–0.02	0.02	0.01
Capital	–0.33	–0.12	–0.02	–0.01	0.06
CV	1.72	1.52	1.38	1.29	1.04

Zambia					
Per capita	2.18	2.18	2.18	2.18	2.18
Grains	0.03	0.02	0.01	0.00	–0.01
Livestock	–0.52	–0.18	–0.02	0.07	0.06
Other food	–0.01	0.00	0.00	0.00	0.00
Non-agriculture	–0.01	0.00	0.01	0.01	0.00
Land	0.06	0.02	–0.02	0.01	–0.01
Unskilled labour	0.46	0.30	0.10	0.03	–0.13
Skilled labour	–0.13	–0.13	–0.06	0.04	0.04
Capital	–0.36	–0.21	–0.07	–0.04	0.11
CV	1.71	2.00	2.13	2.29	2.23
*CV = Compensating variation					

Table 7. *Deviations of consumption and incomes shares from per capita household.*

Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	
South Korea					
Grains	0.04	0.02	0.01	0.00	–0.02
Livestock	0.03	0.01	0.01	0.00	–0.01
Land	–0.01	0.00	0.01	0.00	0.00
Unskilled labour	0.61	0.34	0.06	–0.04	–0.21
Skilled labour	–0.13	–0.13	–0.05	0.06	0.05
Capital	–0.46	–0.21	–0.02	–0.02	0.16
Sri Lanka					
Grains	0.05	0.03	0.02	0.01	–0.02
Livestock	0.01	0.02	0.01	0.01	–0.01
Land	–0.05	–0.02	0.01	–0.01	0.01
Unskilled labour	0.56	0.37	0.13	0.04	–0.17
Skilled labour	–0.11	–0.11	–0.05	0.03	0.03
Capital	–0.40	–0.25	–0.09	–0.06	0.13
Thailand					
Grains	0.05	0.03	0.02	0.01	–0.02
Livestock	0.03	0.02	0.02	0.01	–0.01
Land	0.01	0.01	0.01	0.00	–0.01
Unskilled labour	0.74	0.30	0.05	0.00	–0.12
Skilled labour	–0.07	–0.07	–0.02	0.03	0.01
Capital	–0.69	–0.25	–0.04	–0.02	0.11
Zambia					
Grains	0.11	0.06	0.03	0.01	–0.03
Livestock	–0.04	–0.02	0.00	0.00	0.01
Land	–0.02	0.00	0.01	0.00	0.00
Unskilled labour	0.60	0.39	0.13	0.03	–0.17
Skilled labour	–0.10	–0.10	–0.04	0.03	0.03
Capital	–0.49	–0.29	–0.09	–0.06	0.15

At this point, it is helpful to examine a specific case. For quintile 1 of South Korea, it is seen from Table 6 that livestock contributed positively (0.36) and skilled labour contributed negatively (–0.07) to CV, as a percentage of initial expenditure. Recall from Table 4 that in South Korea the consumer price of livestock fell by 13.19% and skilled labour’s wages rose by 0.51%. From Table 7, we find that quintile 1’s expenditure share on livestock was 3 percentage-points above the per capita share, and skilled labour comprises a 13 percentage-point smaller share of income for quintile 1 in South Korea relative to the average South Korean household. The 0.36 and –0.07 figures result from the multiplication of –13.19 by 0.03 (which is then multiplied by –1 as seen from equation 7) and the multiplication of 0.51 by –0.13, respectively.

The biggest share differences in Table 7 are for unskilled labour and capital. Not surprisingly, the low-income households exhibit an above-average reliance on unskilled wages whereas their income share from capital is relatively low. However, since these two shares work in opposite directions and since the returns to these two factors tend to rise at roughly the same rate (Table 5), these are less dominant than the livestock consumption share in determining overall differences in incidence across regions. We found that technical progress in livestock results in a very different pattern of incidence in Zambia compared with the other three countries. In Zambia, wealthier households benefit relatively more than do poor ones. This is not because the patterns of price changes are markedly different in Zambia (Table 4). Instead it is because livestock plays a different role in the consumption patterns of households in Zambia compared with the other three countries (Figure 1). In particular, livestock’s budget share is four percentage-points less important to Zambia quintile 1 than to the average Zambian household. This stands in contrast to Korea, Sri Lanka and Thailand, in which livestock comprises a larger share of quintile 1's budget than it does for the per capita household (Table 7). Since livestock products are less important to poor Zambian households than to wealthier ones, lower Zambian quintiles do not benefit to the same degree from the price drop.

7 Conclusions and directions for future research

There is tremendous interest in analysing the impact of technological progress and economic policy on welfare across the income distribution. This paper outlines a general framework for analysing the impact of any set of commodity and factor price changes on the welfare of disaggregate households. The impact may be decomposed into an average effect and the departures from that average. The latter departures may be attributed to interactions between the commodity price changes and differences in consumption shares, on the one hand, and interactions between factor price changes and differences in factor earnings shares, on the other hand.

Differences in consumption shares across households are estimated at the quintile level, based on a demand system estimated using the International Comparisons Project (ICP) database, together with the World Bank's database on income distribution following the approach developed in Cranfield (1999). The resulting parameter estimates and recovered expenditure distributions reflect the data used during estimation. In particular, quintile data were used to guide the estimation of the expenditure distribution. This approximation could be improved upon provided additional information on the expenditure distribution was available. Moreover, the ICP data set used here is relatively old and does not include countries in Latin and South America. Access to a more recent version of the ICP data, with broader country coverage, would greatly enhance the consumption side of our analysis.

Our estimated differences in factor income shares have weaker empirical foundations. They are obtained by combining information on total factor earnings, with observations on income by quintile and initial estimates of the factor earnings pattern by quintile. Improved estimates of the latter would greatly improve the quality of the resulting incidence analysis.

The proposed framework may be combined with any set of price changes to assess their incidence. For convenience and comparability across countries, we have chosen to use the GTAP model of global trade to estimate the price effects of technological change. We find that, in the case of Korea, Sri Lanka and Zambia, technological change in grains benefits the poorest households relatively more than a comparable improvement in livestock productivity. The opposite is true in Thailand. Also, with the exception of the Zambia livestock sector, technical progress in either livestock or grains benefits poorer households relatively more. This stems primarily from poorer households' heavier reliance on food products in their consumption bundle, although improvements in unskilled wages also play a role.

Future research should consider applying this approach to other problems. For example, there is currently great interest in discussing the impact of trade liberalisation on low-income households. We believe this framework would be well suited to addressing such issues.

Appendix I. Deriving a local approximation to compensating variation

This appendix derives an expression that approximates the compensating variation (CV) associated with a given vector of price changes. We begin with a very general household utility maximising problem, where *Qi* denotes quantity demanded, *P* is price and *Y* is income:

$$(1)\quad \max U(Q_1,\ldots,Q_N) \quad st. \sum_{n=1}^{N} P_n * Q_n = Y$$

Solution of (1) gives rise to the following demand equations

$$(2)\quad Q_n = h(P_1,\ldots,P_N,Y), \forall n = 1\ldots N. \qquad (2)$$

Consider first the implication of the budget constraint by totally differentiating it to obtain:

$$(3)\quad \sum_{n=1}^{N} \theta_n (p_n + q_n) = y$$

where $?_n = P_n Q_n / Y$ is the budget share for good n, and the lower case variables for price, quantity and income denote the logarithmic differentials of these variables, multiplied by 100%.

Next, consider the first order conditions from the consumer's utility maximisation problem:

$$(4)\quad \frac{\partial U}{\partial Q_n} = \psi P_n$$

where Y is the LaGrangian multiplier associated with the consumer's budget constraint. Equation 4 states that the marginal utility of consumption must equal price, weighted by the contribution of another unit of income to utility.

Now, return to the utility function and totally differentiate it:

$$(5) \quad dU = \sum_{n=1}^{N} \left[\partial U / \partial Q_n \right] dQ_n$$

Substitute (ψP_n) in for $(\partial U / \partial \ddot{Q}_n)$ to obtain equation 6:

$$(6) \quad dU = \sum_{n=1}^{N} \psi P_n Q_n \left[\frac{dQ_n}{Q_n} \right]$$

Next factor out P and multiply through y/y to get:

$$(7) \quad \psi Y \sum_{n=1}^{N} \left[\frac{P_n Q_n}{Y} \right] \left[\frac{dQ_n}{Q_n} \right]$$

We can now write equation 7 in terms of budget shares:

$$(8) \quad dU = \psi Y \sum_{n=1}^{N} \theta_n q_n$$

Equation 8 states that, if we want to hold utility constant, we require that the budget share-weighted sum of consumption must equal zero:

$$(9) \quad \text{i.e. } dU = 0 \Leftrightarrow \sum_{n=1}^{N} \theta_n q_n = 0$$

Now recall equation 3:

$$(10) \quad \sum_n \theta_n (p_n + q_n) = y$$

Combining this implication of the budget constraint, with that of utility maximisation, we see that for utility to remain constant, income must vary with the budget share weighted sum of price changes:

i.e. $dU = 0 \Leftrightarrow \sum_n \theta_n p_n = y$. Thus:

$$(11) \quad \sum_n (\theta_n p_n) - y = cv$$

is the compensating variation, expressed as a percentage of initial income (expenditure). This is the amount of transfer required to hold utility constant in the face of price changes. For example, if p_m=1% and p_n=0 $\forall n \neq m$ then y = q_m is the amount of additional income required to compensate the household for this price change.

Appendix II. Demand analysis data description and sources

AIDADS (An Implicitly Directly Additive Demand System) is estimated using a cross section subset of countries from the 1985 International Comparisons Project (ICP). These data are useful in analysing international demand patterns because they are provided in identical units (i.e. International dollars) and facilitate comparison of prices and quantities for disaggregate commodities across countries. ICP data sets have been compiled for the years 1970, 1973, 1975, 1980, 1985, 1990 and 1995. However, at the time of writing this study, the 1985 data set was the most up-to-date publicly available release.

The 1985 data set consists of 64 countries, ranging from Ethiopia, with a real per capita consumption of US$ 159 (1985 International dollars) to the USA, with a real per capita consumption of US$ 8881 (1985 International dollars). The data report final consumption of 113 goods and services. Of the 113 goods and services, food items account for 36 goods. Within the food group, 11 goods are in the livestock category (these include meat, milk, cheese and egg products), 3 goods are in the grains category (rice, flours and cereals, and bread) while the remaining 22 are in the other food category (other bakery products, pasta products, other cereal products, fish, oils and fats, fruit and vegetables, potatoes and tubers, sugar, coffee, tea and cocoa, and other foods).

Budget shares are constructed by dividing nominal expenditure on each aggregate good by total nominal expenditure. The price of each good equals the ratio of total nominal expenditure for that good to total real expenditure for the same good. Total nominal expenditure per capita (stated in hundreds of International dollars) serves as the expenditure term in AIDADS.

The quintile data are obtained from a database described in Deninger and Squire (1996), available at URL: http://www.worldbank.org/html/prdmg/grthweb/dddeisqu.htm. This database is a compilation of inequality measures (Gini coefficients and quintile data)[8] for various countries over time. However, two issues warrant mention. First, not all countries in the 1985 ICP data set are covered in Deninger and Squire's database. Second, even when a country is covered, the year for which the quintiles are provided does not necessarily match the year of the ICP data. In these instances, issues of the World Bank's World Development Report are used as a source of the quintiles.[9]

8. The quintile data specify the percent of economy-wide expenditure held by successive population quintiles ordered by expenditure. For example, the first quintile represents the share of economy-wide expenditure held by the lowest 20% of the population, the second quintile measures the share of economy-wide expenditure held by the second lowest 20% of the population etc. The greater the difference between quintile shares, the greater the extent of inequality. A Gini coefficient provides a single measure of the inequality in the distribution of economy-wide expenditure (or income). Gini coefficients are based on the cumulative share of expenditure held by the cumulative proportion of the population. The higher the value of the Gini coefficient, the greater the level of inequality.

9. The World Development Report was not used as the primary source of the inequality data as it does not cover as many countries as Deninger and Squire's database, and the years of coverage differ substantially from 1985.

Table A1 shows the quintile data, source, year of coverage and mnemonics showing particular measurement details for the 53 countries used to estimate AIDADS. In two instances, the World Development Report is used to obtain quintile data. Note that the year of coverage typically deviates from 1985, but usually by no more than five years, and that the quintiles are measured in different units across countries (i.e. income versus expenditure, households versus individuals, gross versus net of taxes). However, these data are the best source of inequality data that is available. Because the income distribution (and presumably the expenditure distribution) tends to change slowly over time, the mismatch between years for the quintile data is assumed to be unimportant. Due to the high correlation between income and expenditure, gross and net of taxes, and for households versus individuals, this mismatch in the data is also assumed negligible.

Recognise that it is implicitly assumed that goods are homogeneous across expenditure levels within a particular country and across countries. In reality, this assumption is not necessarily true as the horizontal and vertical differentiation of goods is likely to change as expenditure levels rise within a country and as countries move along the expenditure and development spectrum.

Table A1. *Inequality data and description.*

Country	PCE	Q1	Q2	Q3	Q4	Source	Year	Inc.	Pers.	Tax
Ethiopia	89.47	0.0860	0.2130	0.3770	0.5880	WDR–93	1981–1982	N/A	N/A	N/A
Nepal	112.17	0.0911	0.2200	0.3868	0.6050	1	1984	I	P	N
Bangladesh	149.90	0.0699	0.1935	0.3442	0.5397	1	1986	I	H	G
Kenya	196.91	0.0339	0.1011	0.2084	0.3816	1	1981–1983	E	P	N
India	198.64	0.0850	0.2100	0.3740	0.5890	1	1986	E	P	N
Rwanda	229.59	0.0970	0.2279	0.3944	0.6108	1	1983	E	P	N
Zambia	230.33	0.0557	0.1515	0.2931	0.5029	1	1991	E	P	N
Madagascar	261.38	0.0585	0.1565	0.2978	0.5016	1	1993	E	P	N
Pakistan	265.31	0.0854	0.2088	0.3710	0.5863	1	1985	E	H	N
Tanzania	265.60	0.0685	0.1775	0.3303	0.5456	1	1993	E	P	N/A
Sri-Lanka	310.23	0.0506	0.1414	0.2752	0.4761	1	1987	I	H	G
Zimbabwe	337.29	0.0398	0.1027	0.2028	0.3766	1	1990	E	P	N
Senegal	359.22	0.0350	0.1048	0.2207	0.4138	1	1991	E	P	N
Côte-d'Ivoire	416.34	0.0500	0.1300	0.2610	0.4740	WDR–92	1986–1987	I	H	N/A
Morocco	428.10	0.0658	0.1765	0.3296	0.5385	1	1984	E	P	N
Philippnes	434.75	0.0520	0.1430	0.2760	0.4790	1	1985	I	H	G
Thailand	488.75	0.0420	0.1290	0.2600	0.4690	1	1986	I	H	G
Botswana	510.64	0.0360	0.1048	0.2190	0.4111	1	1986	E	H	N
Egypt	535.02	0.0871	0.2120	0.3747	0.5891	1	1991	E	P	N/A
Nigeria	622.66	0.0696	0.1916	0.3523	0.5580	1	1986	E	P	N
Jamaica	657.12	0.0541	0.1519	0.2968	0.5097	1	1988	E	P	N
Mauritius	753.49	0.0590	0.1720	0.3210	0.5430	1	1986	E	P	N
Turkey	781.01	0.0524	0.1485	0.2891	0.5006	1	1987	I	H	G
Tunisa	812.13	0.0586	0.1627	0.3154	0.5367	1	1990	E	P	N/A
Yugoslavia	1035.76	0.0733	0.1971	0.3694	0.6038	1	1985	I	P	G
Poland	1258.31	0.0984	0.2413	0.4219	0.6492	1	1985	I	P	G
Hungary	1302.77	0.1050	0.2510	0.4300	0.6530	1	1987	I	P	N
Republic of Korea	1410.40	0.0680	0.2050	0.3650	0.5810	1	1985	I	H	G
Portugal	1448.15	0.0553	0.1700	0.3391	0.5750	1	1980	I	H	N

Greece	2472.86	0.0619	0.1778	0.3482	0.5882	1	1988	E	H	N
Spain	2900.52	0.0966	0.2356	0.4260	0.6558	1	1985	E	H	N
Barbados	3120.72	0.0225	0.1025	0.2500	0.4900	1	1979	I	H	G
Ireland	3167.35	0.0493	0.1464	0.3048	0.5540	1	1987	I	H	N
Trinidad & Tobago	3865.18	0.0343	0.1354	0.2963	0.5514	1	1981	I	H	G
New Zealand	4150.48	0.0552	0.1714	0.3447	0.5889	1	1985	I	H	G
Hong Kong	4244.46	0.0631	0.1579	0.2977	0.5071	1	1986	I	H	G
Italy	4975.12	0.0820	0.2117	0.3861	0.6178	1	1984	I	H	N
United - Kingdom	5240.54	0.0890	0.2244	0.3877	0.6215	1	1985	I	Pe	N
Austria	5549.50	0.1006	0.2526	0.4415	0.6721	1	1987	I	Pe	N
Netherlands	5949.14	0.0757	0.2152	0.3970	0.6331	1	1985	I	He	N
Belgium	6152.63	0.0860	0.2291	0.4160	0.6526	1	1985	I	H	N
Luxemborg	6296.78	0.0875	0.2267	0.4072	0.6400	1	1985	I	H	N
West Germany	6383.26	0.0659	0.1938	0.3735	0.6112	1	1984	I	H	G
France	6445.32	0.0658	0.1901	0.3575	0.5803	1	1984	I	H	G
Bahamas	6614.25	0.0305	0.1049	0.2480	0.5114	1	1986	I	H	G
Finland	6656.06	0.0680	0.1930	0.3790	0.6300	1	1984	I	H	N
Australia	6670.18	0.0510	0.1560	0.3280	0.5780	1	1985	I	H	G
Denmark	6803.67	0.0521	0.1759	0.3706	0.6222	1	1987	I	H	G
Sweden	6947.09	0.0704	0.2005	0.3798	0.6184	1	1985	I	H	N
Japan	7152.85	0.0590	0.1770	0.3487	0.5818	1	1982	I	H	G
Norway	7683.56	0.0818	0.2087	0.3876	0.6312	1	1985	I	H	N
Canada	8813.03	0.0627	0.1881	0.3665	0.6088	1	1985	I	H	G
USA	12018.52	0.0470	0.1560	0.3240	0.5650	1	1985	I	H	G

PCE = Total nominal expenditure per capita. Source: 1985 ICP data.

Q1 = Cumulative share of total expenditure for the first quintile.

Q2 = Cumulative share of total expenditure for the second quintile.

Q3 = Cumulative share of total expenditure for the third quintile.

Q4 = Cumulative share of total expenditure for the fourth quintile.

Year = Year the quintile data covers.

Inc. = Indicates whether the quintile data are based on income (I) or Expenditure (E)

Pers. = Indicates whether the quintile data are based on households (H), persons (P), household equivalents (He) or person equivalents (Pe).

Tax = Indicates whether the quintile data are net (N) or gross (G) of taxes.

N/A = Information is not available.

Source: A value of 1 indicates Deninger and Squire (1996), while WDR–93 denotes the *World Development Report* (1993) and WDR–92 denotes the *World Development Report* (1992).

Appendix III. Aggregation of regions and commodities in GTAP (Global Trade Analysis Project) analysis

Table A2. *Regional and commodity aggregation by GTAP analysis*.

Regional aggregation		Commodity aggregation	
1	OECD* (less Korea)	1	Grains
	Australia		Paddy rice
	New Zealand		Wheat
	Japan		Cereal grains
	Mexico		Processed rice
	United Kingdom	2	Livestock
	Germany		Cattle, sheep, goats, horses
	Denmark		Animal products
	Sweden		Raw milk
	Finland		
	European Free Trade Association	3	Other agriculture
	Canada		Vegetables, fruit, nuts
	United States of America		Oil seeds
	Rest of European Union		Sugar cane, sugar beet
2	Korea		Plant-based fibres
			Crops
			Wool, silk-worm cocoons
3	Indonesia		
		4	Processed livestock products
4	Thailand		Meat: cattle, sheep, goats, horse
			Meat products
5	Other East Asia		Dairy products
	Malaysia		
	Philippines	5	Processed food products
	Singapore		Vegetable oils and fats
	Thailand		Sugar
	Vietnam		Food products
	China		
	Hong Kong	6	Natural resources
	Taiwan		Forestry
6	India		Fishing
			Coal
			Oil

7	Sri Lanka		Gas
			Minerals
8	South America		
	Central America and Caribbean	7	Beverages and tobacco
	Venezuela		Beverages and tobacco products
	Colombia		
	Argentina	8	Clothing and footwear
	Brazil		Textiles
	Chile		Wearing apparel
	Uruguay		Leather products
	Rest of the Andean Pact		
	Rest of South America	9	Other manufactured products
			Wood products
9	South Africa Customs Union		Paper products, publishing
			Petroleum, coal products
			Chemical, rubber, plastic products
10	Rest of southern Africa		Mineral products
			Ferrous metals
11	Rest of sub-Saharan Africa		Metals
			Metal products
			Motor vehicles and parts
12	Rest of the world		Transport equipment
	Rest of South Asia		Electronic equipment
	Central European Associates		Machinery and equipment
	Former Soviet Union		Manufactures
	Turkey		
	Rest of Middle East	10	Housing and utilities
	Morocco		Electricity
	Rest of North Africa		Gas manufacture, distribution
			Water
			Dwellings
		11	Margin services
			Trade, transport
			Construction
			Finance, business, recreation service
			Public administration, defence, education,

			health

* OECD = Organization for Economic Co-operation and Development.

Appendix IV. General equilibrium own-price elasticities by commodity and region from GTAP (Global Trade Analysis Project) model

Table A3. *Price elasticities by commodity and region by GTAP model.*

	Domestic	Export	Share-weighted total
South Korea farm livestock			
Share	1.00	0.00	
Average elasticity	–0.33	–5.25	–0.35
Sri Lanka farm livestock			
Share	0.99	0.01	
Average elasticity	–0.16	–5.47	–0.21
Thailand farm livestock			
Share	0.98	0.02	
Average elasticity	–0.71	–5.22	–0.82
Zambia farm livestock			
Share	0.97	0.03	
Average elasticity	–0.16	–4.71	–0.29
South Korea grains			
Share	1.00	0.00	
Average elasticity	–0.30	–4.04	–0.30
Sri Lanka grains			
Share	0.99	0.01	
Average elasticity	–0.37	–3.97	–0.40
Thailand grains			
Share	0.63	0.37	
Average elasticity	–1.64	–3.53	–2.33
Zambia grains			
Share	0.96	0.04	
Average elasticity	–0.48	–2.95	–0.57

Appendix V. Comparison of equivalent variation, compensating variation and approximate compensating variation

Table A4. *Effect of a 5% cost reduction due to technical change in livestock.*

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
South Korea					
Equivalent variation	1.86	1.47	1.37	1.33	1.06
Compensating variation (CV)	1.74	1.38	1.29	1.25	1.00
Approximate CV	1.74	1.37	1.28	1.25	0.99
Sri Lanka					
Equivalent variation	1.58	1.38	1.19	1.26	0.90
CV	1.55	1.36	1.17	1.24	0.89
Approximate CV	1.55	1.35	1.16	1.23	0.88
Thailand					
Equivalent variation	1.79	1.58	1.44	1.34	1.08
CV	1.71	1.51	1.37	1.28	1.03
Approximate CV	1.72	1.52	1.38	1.29	1.04
Zambia					
Equivalent variation	1.81	2.13	2.27	2.44	2.38
CV	1.71	2.00	2.12	2.29	2.23
Approximate CV	1.71	2.00	2.13	2.29	2.23

Table A5. *Effect of 5% cost reduction due to technical change in grains*

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
South Korea					
Equivalent variation	2.25	1.46	1.28	1.24	0.75
Compensating variation (CV)	2.11	1.37	1.20	1.17	0.71
Approximate CV	2.10	1.36	1.20	1.16	0.70
Sri Lanka					
Equivalent variation	2.34	1.90	1.57	1.47	0.81
CV	2.23	1.80	1.48	1.39	0.76
Approximate CV	2.24	1.80	1.48	1.39	0.76
Thailand					
Equivalent variation	1.75	1.42	1.20	0.92	0.61
CV	1.71	1.39	1.17	0.90	0.60
Approximate CV	1.68	1.36	1.14	0.87	0.57
Zambia					
Equivalent variation	4.29	3.58	3.22	2.98	2.37
CV	4.14	3.42	3.06	2.82	2.24

Approximate CV	4.14	3.42	3.06	2.82	2.24

Appendix VI. Decomposition of compensating variation (CV) for technical progress in the grains sector

Table A6. *Decomposition of (CV) in the grains sector.*

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
South Korea					
Per capita	1.07	1.07	1.07	1.07	1.07
Grains	0.71	0.29	0.19	0.02	–0.29
Livestock	0.09	0.04	0.03	0.00	–0.04
Other food	0.24	0.10	0.07	0.01	–0.10
Non-agriculture	0.03	0.01	0.01	0.00	–0.01
Land	0.17	–0.03	–0.14	0.04	0.01
Unskilled labour	0.23	0.13	0.02	–0.02	–0.08
Skilled labour	–0.10	–0.10	–0.03	0.05	0.04
Capital	–0.32	–0.15	–0.01	–0.01	0.11
Compensating Variation (CV)	2.10	1.36	1.20	1.16	0.70
Sri Lanka					
Per capita	1.15	1.15	1.15	1.15	1.15
Grains	0.71	0.47	0.32	0.15	–0.29
Livestock	0.00	–0.01	0.00	0.00	0.00
Other food	0.00	0.00	0.00	0.00	0.00
Non-agriculture	0.08	0.06	0.05	0.03	–0.04
Land	0.13	0.05	–0.04	0.02	–0.02
Unskilled labour	0.57	0.38	0.13	0.04	–0.17
Skilled labour	–0.15	–0.15	–0.07	0.04	0.04
Capital	–0.25	–0.16	–0.06	–0.04	0.08
CV	2.24	1.80	1.48	1.39	0.76
Thailand					
Per capita	0.82	0.82	0.82	0.82	0.82
Grains	0.42	0.28	0.19	0.07	–0.15
Livestock	–0.01	–0.01	–0.01	0.00	0.01
Other food	–0.05	–0.04	–0.03	–0.01	0.02
Non-agriculture	0.01	0.01	0.01	0.00	–0.01
Land	0.10	0.13	0.13	–0.01	–0.06
Unskilled labour	0.41	0.17	0.03	0.00	–0.07
Skilled labour	–0.01	–0.01	0.00	0.00	0.00
Capital	–0.01	–0.01	0.00	0.00	0.00
CV	1.68	1.36	1.14	0.87	0.57
Zambia					
Per capita	2.67	2.67	2.67	2.67	2.67
Grains	1.56	0.82	0.43	0.12	–0.46

Livestock	–0.03	–0.01	0.00	0.00	0.00
Other food	–0.02	0.00	0.00	0.01	0.00
Non-agriculture	0.00	0.00	0.00	0.00	0.00
Land	0.04	0.01	–0.01	0.00	0.00
Unskilled labour	0.31	0.20	0.07	0.02	–0.09
Skilled labour	–0.10	–0.10	–0.05	0.03	0.03
Capital	–0.28	–0.17	–0.05	–0.03	0.08
CV	4.14	3.42	3.06	2.82	2.24

Appendix VII. Description of the spreadsheet model

The Excel © workbook that serves to perform the analysis described in this report is organised into several worksheets. This appendix briefly describes the contents and function of each of these worksheets and indicates appropriate locations for user changes. The names of the worksheets are: Introduction, ICPData, Margins, FactInc, GTAPResults, QuintImpact, PoorImpact, Decomp and Calc. There are numerous, complex linkages between the worksheets that require caution in their modification. The authors recommend that an archival copy be maintained that is never changed as a precaution against inadvertent modification of the underlying relationships.

Introduction

The Introduction worksheet is purely text. There are no links to this worksheet from other worksheets. The text describes the general purpose of the entire workbook and details the correspondence between GTAP (Global Trade Analysis Project) goods and the goods used in the present analysis. The definitions of the variables from GTAP that are employed in the analysis (in other worksheets as indicated below) are also listed along with a few of the basic properties of the GTAP model.

ICPData

The worksheet ICPData contains price data from the ICP (International Comparisons Project) database. To the left of the price data appear GDP (Gross Domestic Product) growth rates from 1985–95 along with fitted shares from the AIDADS (An Implicitly Directly Additive Demand System) estimation programme for consumption quantities in both 1985 and 1995. The 1995 values also appear below the price data under the title Fitted quantities from AIDADS estimation updated to 1995. Below this quantity appears the quintile information. These data serve as inputs to other worksheets.

Margins

The Margins worksheet computes the share of margin services in consumer expenditures by good and country. The basic inputs to these calculations are consumption shares by country at the ten GTAP producer good-level exogenous assumptions regarding the percentage of the value of the producer good that must be added in terms of marketing services to produce a consumer good. (For our initial calculations, these percentages were assumed to be 20% for farm produce and 50% for processed products and other manufactured products.)

These figures are then combined via the aggregation mapping from GTAP to ICP goods (described in the Introduction worksheet) to obtain fractions of the value of the producer goods that must be used to transform the producer goods to consumer goods. The final step is to convert these values to fractions that indicate the proportion of the value of producer goods that is attributable to marketing margins. These marketing margins are employed in the QuintImpact worksheet to convert producer good prices from GTAPResults to ICP-equivalent consumer good prices.

FactInc

The FactInc worksheet is used to calculate the shares of income attributable to factors (land, unskilled labour, skilled labour and capital) for each country. The first table in the worksheet lists the levels of income in the initial equilibrium for each factor and country. (In the present case, these come from the GTAP pre-shock equilibrium.) The second table simply converts these figures to share form. These shares serve as inputs to the QuintImpact worksheet.

GTAPResults

The GTAPResults worksheet contains the price impacts of the simulated shock (e.g. increased livestock productivity in a particular region) and organises most of the inputs for the QuintImpact worksheet. This worksheet is intended to be the primary interface for input of changes for the casual user of the workbook. In addition to the relevant numbers, comments are included that indicate where these numbers can be found in the workbook. The numbers that drive the analysis are highlighted in blue, and instructions for where to find them are highlighted in brown. In copying values to replace the blue-highlighted numbers, be sure to use the 'Edit of Paste Special Values' editing feature in Excel. The bottom half of this worksheet includes the tables of GTAP results for changes in consumer and factor prices. The tables copied from RunGTAP are 'ppagg', 'pm' and 'pfactor', and are the source of some of the blue values pasted at the top of the worksheet.

QuintImpact

This worksheet displays the basic results for the analysis at the quintile level. The top-most section of the spreadsheet displays the estimated parameters for the AIDADS demand system. The next section displays the target levels for the ownership shares of the factors of production. These are taken as input to the RAS (row and column sum) matrix-balancing algorithm. (The RAS algorithm is applied in the Calc. worksheet, which is described below.) Thus, these targets may be adjusted here if desired. The next section displays the adjusted factor ownership shares. These cannot be adjusted directly —the targets must be adjusted to adjust the final shares.

The next section of the worksheet (titled *Factor income by quintile—before the shock)* displays the calculation of household income by quintile prior to the shock. The next three blocks of the worksheet (titled *Base prices and quantities for goods from ICP data, Percentage changes in prices of goods from GTAP and Prices of goods after the shock*) compute the after-shock consumer goods prices by applying the percentage changes from GTAP to the base prices and adjusting for margins. (Note that the change in the price of margin services is also taken into account in this calculation.)

The next two sections (titled Percentage changes in factor prices from GTAP and Factor income by quintile—with the shock) calculate adjustments to factor income by quintile. The next two sections (titled Expenditure—before the shock and Expenditure—after the shock) display expenditure by commodity and quintile, both before and after the shock. As part of these calculations, the level of utility that satisfies the AIDADS defining relationship must be computed. These calculations occur in the Calc. worksheet, which is described below. The next section of the worksheet (titled *Equivalent variation*) calculates the equivalent variation—the amount of money one must give to the consumers to allow them to attain the after-shock level of utility at pre-shock prices. This is calculated directly in three steps. First, the level of income needed to attain after-shock utility at pre-shock prices is computed. Second, the pre-shock level of income is subtracted. Third, this income difference is converted to percentage terms. The last four sections of the worksheet display percentage changes in expenditure due to the shock, percentage changes in quantities demanded due to the shock, and budget shares before and after the shock, all by quintile and commodity.

PoorImpact

The PoorImpact worksheet reproduces much of the analysis that appears in QuintImpact, but under simplified assumptions about factor ownership. In this worksheet, hypothetical households that are completely specialised in their factor ownership and near the subsistence level are examined. The endowment of each factor is set at a level that is just high enough to ensure that consumers will have 110% of the maximum of the income needed to satisfy subsistence before and after the shock. Thus, regardless of whether household income goes up or down due to the shock, income will be sufficient both before and after the shock to purchase the subsistence consumption bundle.

Under this simplified framework, many of the calculations from QuintImpact may be referenced directly from that sheet (e.g. consumer and factor price changes due to the shock). The results are then displayed in sections similar to those in QuintImpact and titled *Expenditure before shock, Expenditure after shock, Equivalent variation, Budget shares—before shock and Budget shares—after shock*.

Decomp

The Decomp. worksheet displays the numerical breakdown of compensating variation (CV) into per-capita and quintile-specific components for each of the five quintiles. The methodology is based directly on equation 7 of this paper. The numerical breakdowns are summarised in blue at the bottom of the worksheet and the differences that lead to these results are presented in green.

Calc.

The Calc. worksheet takes care of internal computations. These include application of the RAS algorithm to the balancing of the matrix of factor ownership shares, calculating the utility levels for each household before and after the shock that satisfy the AIDADS defining constraint. The implementation of the RAS algorithm is as described in Schneider and Zenios (1990). The utility-level satisfying utility defining constraint is solved by the method of bisector as described in Gill et al. (1981).

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