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The Development Policy Evaluation Model (DEVPEM)

TECHNICAL DOCUMENTATION

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Abstract

THE DEVELOPMENT POLICY EVALUATION MODEL (DEVPEM): TECHNICAL DOCUMENTATION

by

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This paper provides technical documentation of the Development Policy Evaluation Model (DEVPEM model). It contains a discussion of the theoretical building blocks of the model; an overview of the data sources used for the simulations; and explanations of how household groups are categorized and how the model is calibrated. Finally it describes the design of the agricultural policy simulations that are examined in the accompanying policy paper.

Keywords: Agricultural policy, household analysis, welfare, general equilibrium

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THE DEVELOPMENT POLICY EVALUATION MODEL (DEVPEM): TECHNICAL DOCUMENTATION

This paper provides technical documentation of the DEVPEM model. Section 1 discusses the theoretical building blocks of the model; Section 2 gives an overview of the data sources used for the simulations, the categorisation of household groups, and the calibration of the model; Section 3 describes the design of the agricultural policy simulations; Section 4, lastly, summarises and concludes. The analysis and discussion of the policy simulation results are available in the OECD report "Modelling the Distributional Impacts of Agricultural Policies in Developing Countries: The Development Policy Evaluation Model (DEVPEM)" *(OECD Agriculture, Food and Fisheries Working Paper* N°50).

1. Theory and model design

DEVPEM is a disaggregated rural economy-wide model, in the spirit of Taylor *et al.* (2005). It incorporates multiple types of producer-consumer agricultural households, which together represent a partition of the rural economy. A variety of farm-households can be distinguished, for example according to farm size or income sources. The model features a representative household for each of those household types, who then interact with one-another through factor and commodity markets. The production and consumption decisions of all actors are thus interlinked in a general-equilibrium fashion.

One key feature of the model is that it recognises the importance of transaction costs and the possibility that some households are prevented from participating to markets by prohibitive transaction costs. Some of the household types of the model can be "remote" or "subsistence" households, who use their agricultural output for home consumption. In the simulations, the model lets those households endogenously determine their market participation status as market conditions change. Another feature is the imperfect convertibility of land among agricultural crop and livestock activities, which was a feature originally developed for PEM. This section describes the mathematical statement of the model, along with the theoretical underpinnings that motivated it.

DEVPEM notation

Sets, subsets, and elements	
GF (gf)	*Goods and factors*
G (g)	*Goods*
F (f)	*Factors and inputs*
FF (ff)	*Fixed factors*
TF (tf)	*Tradable factors and inputs*
A (a)	*Agricultural activity*
η	*Node of agricultural activities*
MAH ((a,h))	*Mapping of A to H (Activities to households that do them)*
MAG ((a,g))	*Mapping of A to G (Activities to the goods they produce)*
Variables	
QC	*Quantity consumed*
QB	*Quantity bought*
QS	*Quantity sold*
QP	*Quantity produced*
P	*Price*
Y	*Income*
FD	*Factor demand*
R	*Fixed factor rents*
Endow	*Factor endowment*
W	*Wage*
INPP	*Input price*
INPS	*Input supply*

Households in DEVPEM

The basic building block of DEVPEM is the agricultural household model, in which production, consumption and labour allocation decisions may be interdependent (Singh *et al.*, 1986). The farm household maximises its utility from the consumption of goods, which can be purchased goods or home-produced goods. To produce agricultural goods, endowments of labour and fixed productive assets are combined with purchased inputs under a given production technology. The household's consumption is constrained by its farm profits and income from marketed factors of production, such that the total value of goods consumed, evaluated at market prices, is equal to the sum of all profits and the total market value of all endowments (also called "full income"). We now describe these aspects in detail.

Consumption and production problems

On its consumption side, household h is assumed to solve a standard utility maximisation problem. It faces a set G of goods g, of which it chooses quantities consumed ($QC_{h,g}$), and the consumption bundle provides it with a utility U. The household values those goods at price $P_{h,g}$ and acquires them by drawing from its income Y_h. Formally, the problem can be formulated as:

$$\max_{QC} U\left(QC_{h,g}\right) \text{ subject to } \sum_{g} QC_{h,g} \cdot P_{h,g} \leq Y_h \qquad (1)$$

This same household may also be engaged in agricultural production. On its producer side, it seeks to maximise profit Π_a from each agricultural activity a. Drawing from a set F of factors and inputs f, the household chooses factor demands $FD_{a,f}$ that will produce an output QP_a. Activity factors, tradable inputs and outputs are valued at rents $R_{a,f}$ or prices $P_{a,gf}$ (where the index f denotes "factors" and index gf "good or factors"). Formally, this problem can be formulated as:

$$\max \Pi_a = QP_a \cdot P_{a,g} - \sum_{f \in F} FD_{a,f} \cdot P_{a,f} + FD_{a,f} \cdot R_{a,f}$$

subject to: (2)

$$QP_a = QP_a\left(FD_{a,f}\right)$$

The income link

The link between the producer and consumer side of the household is its income.[1] The level of income results partly from the solution to the producer problem, and it imposes the constraint on the consumer problem. The "full income" of the household is equal to the total value of a household's endowments of factors:

$$Y_h = \sum_{tf \in TF} Endow_{h,tf} \cdot P_{h,tf} + \sum_{ff \in FF} \sum_{a \in MAH} FD_{a,ff} \cdot R_{a,ff} \qquad (3)$$

E

1. Another link could be the labour/leisure trade-off, but it is not considered in the current version of DEVPEM.

ndowments $Endow_{tf}$ of each tradable factor *tf* (such as labour), are valued at price $P_{h,tf}$. There is no such single price for fixed factors *ff* (such as land and capital), because their value depends on the activity *in which* they are being used. The amount $FD_{a,ff}$ of a fixed factor *ff* used in activity *a* is valued at rent $R_{a,ff}$. The total value of a household's fixed factor endowments is therefore the sum of fixed factors demands $FD_{a,ff}$ used in all activities (the set *MAH* maps households to their activities).

Solution to the household's problem

We impose functional forms on the utility and production functions to derive analytical solutions to the dual optimisation problem of the household. In DEVPEM, household utility follows a linear expenditure system (LES) specification, with uncompressible consumption $c_{h,g}$ and share parameters $\alpha_{h,g}$ for a given household h and good g. Production follows a Cobb-Douglas function with a shift parameter b_a and exponents $\beta_{a,f}$, expressed as:

$$QP_a = b_a \prod_{f \in F} \left(FD_{a,f}\right)^{\beta_{a,f}} \tag{4}$$

The optimal consumption decisions ($QC_{h,g}$) and factor demands ($FD_{a,f}$) are, respectively:

$$QC_{h,g} = \frac{\alpha_{h,g}}{P_{h,g}} \left(Y_h - \sum_G P_{h,g} c_{h,g} \right) + c_{h,g} \tag{5}$$

and

$$\begin{cases} FD_{a,tf} = \dfrac{P_{(a,g) \in MAG} \cdot QP_a \cdot \beta_{a,tf}}{P_{a,tf}} \text{ for tradable factors } (tf) \\ FD_{a,ff} = \dfrac{P_{(a,g) \in MAG} \cdot QP_a \cdot \beta_{a,ff}}{R_{a,ff}} \text{ for fixed factors } (ff) \end{cases} \tag{6}$$

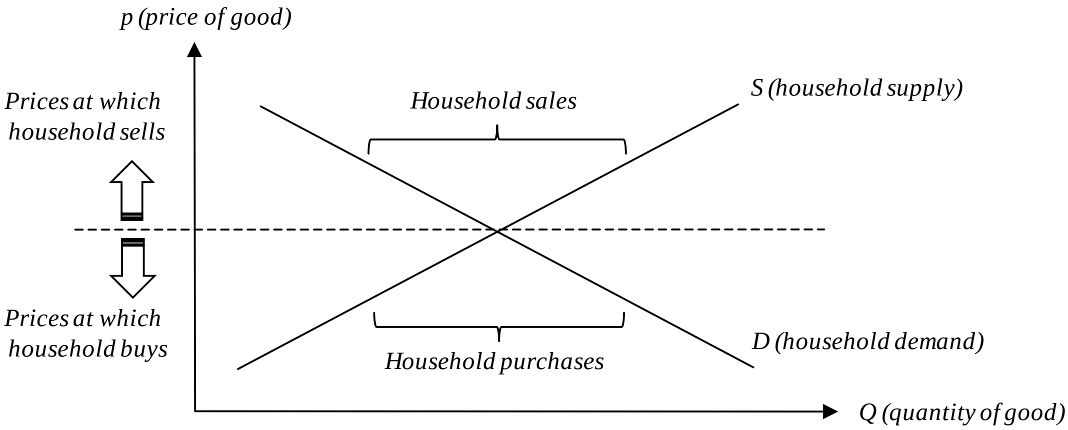
Transaction costs and market participation

Equations (1) through (6) describe the optimal behaviour of a representative household h under a set of commodity prices, input prices, and factor rents. Despite the dual nature of the household as a producer and consumer of agricultural goods, as long as all prices are exogenous, the household can solve the consumer problem and the producer problem independently (Taylor and Adelman, 2003).

The farm household can be thought of as solving two sequential problems: first it maximises its total income as a producer, given prices of inputs and outputs, and then it uses that income to maximise its utility, given prices of consumption goods. The profit-maximising quantity produced [equation (4)] and the utility-maximising quantity consumed [equation (5)] are independent: the problems are said to be "separable." For each good, the difference between amounts produced and consumed determines whether the household is a seller (positive surplus) or buyer (negative surplus). This is illustrated in Figure 1 in the case of linear supply and demand: the market price determines the position of the household as a net buyer or net seller for a certain good. Only when the market price is exactly at the level that equates the quantity demanded and quantity supplied by the household (i.e. at the intersection of the household supply and demand curves) is the household self-sufficient. At all prices above this level, the household is a net seller, selling the quantity made up by the vertical distance between the demand curve (*D*) and the supply curve (*S*) at the going market price. At all prices below this level, the household is a net buyer, purchasing the quantity made up by the vertical distance between the supply curve and the demand curve.

The separable case may adequately depict the decisions of a typical commercial farmer in a high-income country. In much of the developing world, however, a large number of rural households practice subsistence or semi-subsistence farming. They neither buy nor sell certain commodities, but produce exactly what they consume. This is not because the market price happens to be at the exact level equating household supply and demand. Rather, the household is likely to be relying on self-sufficiency because it is isolated from markets by high transaction costs.

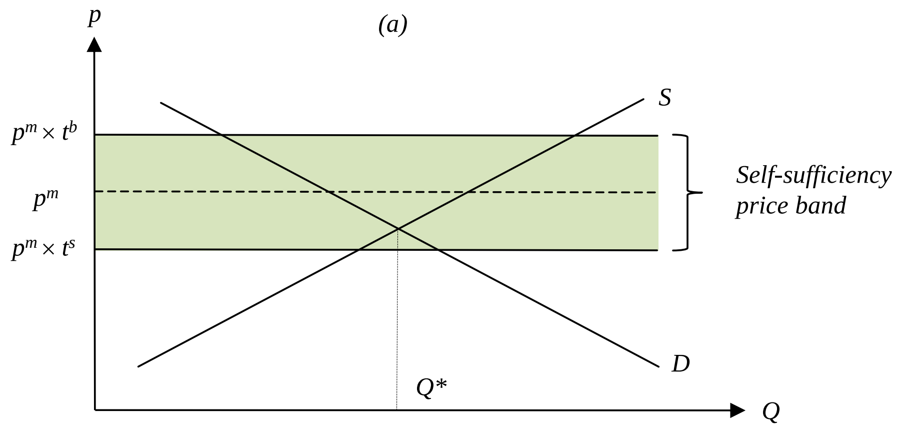
Figure 1. The farm household as a net seller or net buyer depending on the market price

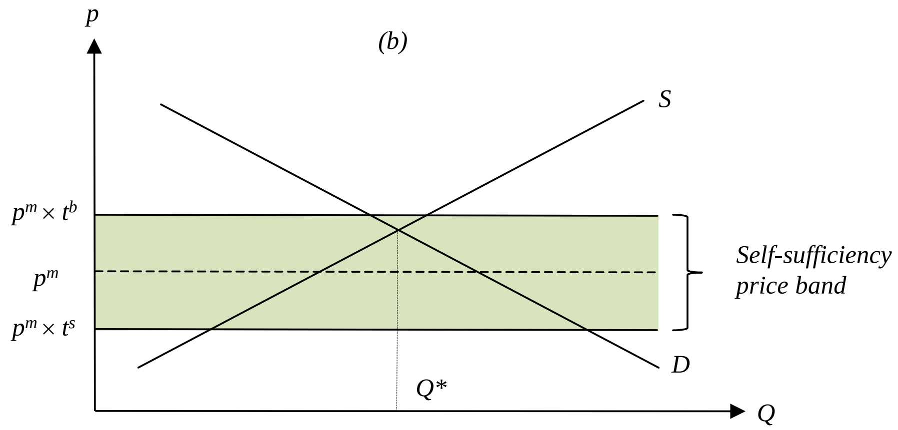


Note: The figure illustrates how the market price determines the position of the household as a net buyer or net seller for a certain good in the absence of transaction costs. At prices above the intersection of the supply and demand curve, the household is a net seller. At all prices below this level, the household is a net buyer.

Transaction costs are any costs that an agent incurs in order to perform a market transaction. They are caused by, for example, long distances to markets, high transportation costs, poor infrastructure, non-competitive market structures, and incomplete information. A buyer facing transaction costs perceives the effective price of commodities it wants to buy as higher than the market price. If the cost associated with buying on the market is prohibitive, a household may prefer not to purchase. Similarly, a seller facing transaction costs perceives the effective price as lower than the market price. If this effective selling price is too low, a household may prefer not to sell the commodities it produces, but use them for own consumption. Under such conditions, households may choose to live in partial or total autarky. The household then produces what it wants to consume, and the dual problems of utility and profit maximisation become "non-separable". As this situation is widespread in developing countries, DEVPEM was designed to capture transaction costs and market participation decisions.

Figure 2. Self-sufficiency in the presence of transactions costs





Note: Graph (a) illustrates how the household optimally chooses self-sufficiency over being a net seller at the market price (p^m) in the presence of buyer transaction costs t^b. Graph (b) shows the case where the household optimally chooses self-sufficiency over being a net buyer at market price (p^m). As long as the market price varies within the price band, whose width is determined by the transaction costs, the household does not respond to price changes.

The treatment of market transaction costs is one of the key aspects in which DEVPEM differs from most general equilibrium models.[2] In DEVPEM it is assumed that certain household groups face proportional (or multiplicative) transaction costs when participating in markets. As buyers of consumption goods and inputs these household face an effective buying price ($p^m \times t^b$) that is higher than the market price ($t^b \geq 1$). As producers, they face an effective selling price ($p^m \times t^s$) that is lower than the market price ($t^s \leq 1$). These transaction costs create a wedge between market price, effective buyer price and effective seller price. Figure 2 illustrates this situation. Part (a) of the figure shows how, in the presence of buyer transactions costs (t^b) and seller transactions costs (t^s), the household optimally chooses self-sufficiency over being a net seller at the current market price, p^m. In the absence of transactions costs, the household would be a net seller, but with seller transactions costs, it receives only $p^m \times t^s$ as the effective seller price, which is lower than its shadow price of the good. The household does not participate in

2. The model by Löfgren and Robinson (1999) is an exception, which helped inspire this work. Transaction costs in partial equilibrium farm household models are discussed by de Janvry *et al.* (1991), Key *et al.* (2000), and de Janvry and Sadoulet (2009).

the market in this case, but instead produces and consumes quantity $Q*$ of the good. Part (b) of the figure shows the opposite case: the household optimally chooses self-sufficiency over being a net buyer at the current market price, p^m. In the absence of transactions costs, it would be a net buyer, but with buyer transactions costs, it faces the effective buyer price $p^m \times t^b$, which is higher than its shadow price of the good.

The price at which the household values a commodity thus depends on its trading status. A net seller values it at $p^m \times t^s$, a net buyer at $p^m \times t^b$, and a subsistence household at a shadow price in between those two values, determined by the intersection of household supply and demand. Formally this can be stated as:

$$\begin{cases} P_{h,g} \leq p_g^m \cdot t_{h,g}^b \\ P_{h,g} \geq p_g^m \cdot t_{h,g}^s \\ QB_{h,g}\left(P_{h,g} - p_g^m \cdot t_{h,g}^b\right) = 0 \\ QS_{h,g}\left(P_{h,g} - p_g^m \cdot t_{h,g}^s\right) = 0 \end{cases} \tag{7}$$

The first expression states that the upper bound of the household shadow price (P_h) for each good g is determined by the market price (p^m) multiplied by the buyer transaction cost factor (t^b). The lower bound is determined similarly by the market price multiplied by the seller transaction cost factor (t^s). The third and fourth expressions are the so-called complementary slackness conditions implying that the household uses its own internal shadow price ($P_{h,g}$) if and only if it does not participate in the market for good g (if quantities sold ($QS_{h,g}$) and bought ($QB_{h,g}$) are both zero).

Having transaction costs in the model also requires that we explicitly express a cash constraint for households. Equation (8) states that the total value of goods and tradable factors that a household can purchase is constrained by its total *cash* income: the market sales of goods and tradable factors plus any exogenous income $exinc_h$ (as opposed to the *full* income Y_h which is the total value of endowments):

$$\sum_{gf \in N} QS_{h,gf} \cdot P_{h,gf} + exinc_h \geq \sum_{gf \in N} QB_{h,gf} \cdot P_{h,gf} \tag{8}$$

It is worth noting that while this explicit accounting for the role of transaction costs may capture an important aspect of developing country agriculture, additional constraints in input markets (e.g. seasonal cash or credit constraints) may impede the ability of households to respond to higher prices, even when the difference between the market price and shadow price exceeds transaction costs in the output market. Such additional constraints can be imposed on the model, and their implications assessed.

Market assumptions in DEVPEM

DEVPEM was designed with developing country applications in mind. We assume that those countries are price takers on world commodity markets. Therefore, agricultural commodity prices are exogenously fixed for households participating in markets (and endogenous for subsistence households). Any surplus from the sector is exported out of the rural sector the “rest of the world” (which includes the urban sector) at world prices. Conversely, any excess demand of agricultural commodities is imported from the rest of the world. This is expressed in a quantity balance equation for all agricultural goods:

$$\sum_{h \in H} QS_{h,g} + QM_g = \sum_{h \in H} QB_{h,g} + QE_g \tag{9}$$

The market for intermediate agricultural inputs (e.g. seeds and fertiliser), on the other hand, follows an imperfectly elastic structure. Inputs suppliers are assumed to be outside of the rural economy, thus exogenous to the model. However, we want to allow for cases where input suppliers benefit from a monopolistic market structure, or cases where rigidities along the distribution chain impose rising marginal costs. Therefore, input supply is modelled as an increasing function of the price, with a constant price elasticity of supply. This is expressed in equation (10), where *INPS* is the input supply, *INPP* the input price (the 0 subscript denotes the base level), and ε_{input} the elasticity:

$$\frac{INPS}{INPS_0} = \left(\frac{INPP}{INPP_0}\right)^{\varepsilon_{input}} \tag{10}$$

Labour is a tradable factor in the model. Households choose how much labour to use for production, drawing either from their own labour resources or hiring from other households. Both types of labour are assumed to be freely substitutable, and the marginal value of household labour is equal to the rural wage. Household labour endowment is fixed, and although households may change the amount of labour to supply to or demand from the rural labour market, the total amount of labour in the economy is assumed to be fixed. This leads to an endogenously determined rural wage which, for simplicity, is assumed to be equal for all households.

Fixed factor allocation in DEVPEM

DEVPEM includes two fixed factors of production: land and capital. The treatment of capital is simple, assumed to be fixed in the short run for all households and activities. This means that reallocation of capital is impossible, and that the value of capital is endogenously determined by a household- and activity-specific capital rent.

The treatment of land is more complex. Many agricultural household models assume that land is a fixed input in each production activity. This assumption may be appropriate in the very short run, or when policies, customs or other considerations impede the smooth functioning of local land markets, as often is the case in developing countries. In the medium to long run, however, some land re-allocation across activities is likely to occur in response to policy changes. If a household's total land endowment is fixed but this land is perfectly transformable from one use to another, the activity-specific land constraints are replaced by a total household land endowment constraint:

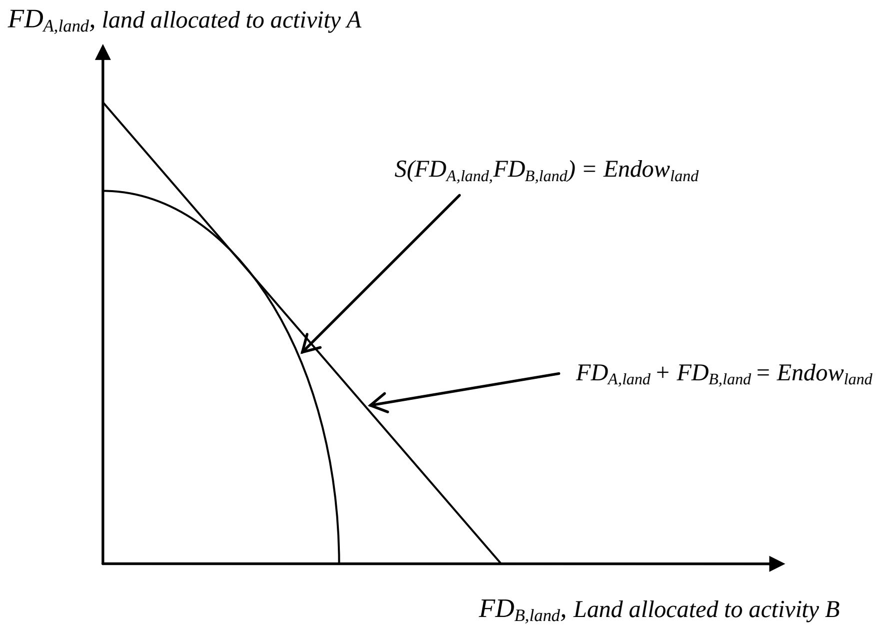
$$Endow_{land} = \sum_{g \in G} FD_{g,land} \tag{11}$$

where $Endow_{land}$ denotes the household's land endowment and $FD_{g,land}$ is the amount of land used in production of good g. DEVPEM follows the OECD PEM model in assuming that land may be transformable from one use to another, albeit imperfectly (OECD, 2005). Imperfect transformability of land among different agricultural uses can be represented by replacing the above equation with a continuous and convex land supply function *S* replacing the linear constraint on land:

$$Endow_{land} = S(FD_{g,land}) \quad (12)$$

The difference between linear and non-linear forms of land transformation can be illustrated in a diagram with two agricultural activities A and B. As shown in Figure 3, with perfect land transformability, the land allocation between the two activities is given by a straight line, indicating that the sum of land is constant ($FD_{A,land} + FD_{B,land} = Endow_{land}$). Instead, when land is imperfectly transformable between activities, land allocation is non-linear and the maximum amount of land available for activity *A* and for activity *B* may differ. The convex curve implies that, on the margin, more and more units of land need to be given up in activity *A* in order to increase land use by one unit in activity *B*, and vice versa. That is the type of structure we impose on land reallocation decisions in DEVPEM.

Figure 3. Perfect versus imperfect land transformability



Note: The diagram shows how land may be allocated between two agricultural activities under linear and non-linear land supply. With perfect land transformability, land allocation between the two activities is characterised by a straight line, indicating that the sum of land is constant ($FD_{land,A} + FD_{land,B} = Endow_{land}$). When land is imperfectly transferable between activities, land allocation is non-linear and the maximum amount of land available for activity *A* and for activity *B* may differ.

DEVPEM has three levels of land transformability (or "nodes", designed by the letter η), each with a different elasticity of transformation.[3] Figure 4 illustrates the idea. First, a distinction is made between land used for permanent cash crops and all other uses. Re-allocation of land at this level is assumed to be relatively difficult (indicated by the substitution parameter σ_1). At the second level of transformability, a distinction is made between pasture land and annual crops. Finally, at the third level, a distinction is made between food crops and annual cash crops, between which land is assumed to be relatively easier to re-allocate. Thus, σ_1 is smaller than σ_2, which in turn is smaller σ_3. For each of these three levels of land transformability, one can think of a diagram similar to that in Figure 3, where activities *A* and *B* are replaced by the three pairs of activities shown in Figure 4.

DEVPEM imposes a constant elasticity of transformation (CET) structure on land allocation. At each node η the total land allocation $FD_{\eta,land}$ is defined as a constant elasticity function of the factor demands in activities pertaining to that node, with household-specific parameters γ_a and ρ_h^η .

$$FD_{\eta,land} = \left(\sum_{a \in \eta} \gamma_a \cdot \left(FD_{a,land} \right)^{\rho_h^\eta} \right)^{1/\rho_h^\eta} \tag{13}$$

The optimal amounts of land allocated to each activity can be found analytically by constrained optimisation. At each node, equation (14) describes the relation between of optimal amounts of land in each activity as a function of their relative rent values in each activity.

$$\frac{R_{a,land}}{R_{a',land}} = \frac{\gamma_{h,a}}{\gamma_{h,a'}} \cdot \left(\frac{FD_{a,land}}{FD_{a',land}} \right)^{\rho_h^\eta - 1} \tag{14}$$

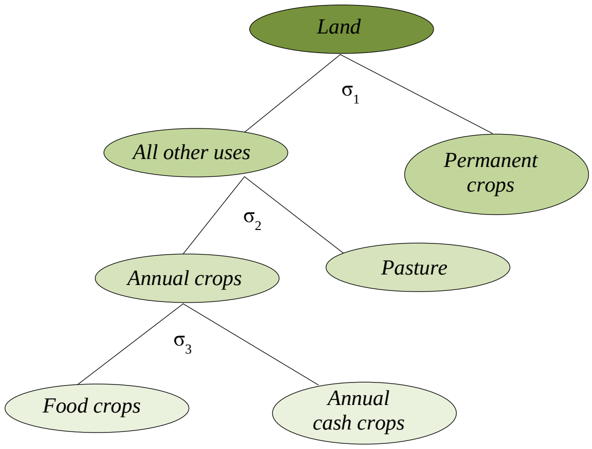
The optimal rent values at each node are in turn given by:

$$R_{\eta,land} = \left[\sum_{a \in A_\eta} (\gamma_a)^{\frac{1}{1-\rho_h^\eta}} \cdot (R_a)^{\frac{\rho_h^\eta}{\rho_h^\eta - 1}} \right]^{\frac{1-\rho_h^\eta}{\rho_h^\eta}} \tag{15}$$

As a system, equations (13), (14), and (15) describe a single optimal solution to the land allocation problem. This concludes the technical description of DEVPEM. A full table of the variables, parameters, and equations is provided in Annex 1.

3. The elasticity of transformation is defined as the percentage increase in land use in one activity, given a 1% decrease in land use in the other activity. Land transformability across activities is modelled in DEVPEM with a constant elasticity of transformation (CET) function.

Figure 4. The three levels of land transformability in DEVPEM



2. Data sources, parameter assumptions, and other model specifics

Country sample and data sources

We constructed DEVPEM models for Bangladesh, Ghana, Guatemala, Malawi, Nicaragua and Viet Nam. Our choice of countries was guided by geographic location (two African, two Latin American and two Asian countries), the possibility of establishing a common data platform, and the scope for exploring the implications of significant structural differences across countries. The countries have several structural differences, both at the macro and micro levels. At the macro level, the six countries differ by population size, income levels (and hence poverty levels), industrial composition, and character of the agricultural sector. At the micro (household) level, there are marked differences between the countries in asset ownership, crop mix, and market integration.

To construct DEVPEM models that generate results that are comparable across countries, a key prerequisite is the availability of data that are fairly comparable across countries. Therefore, countries were chosen that were all part of the *Rural Income Generating Activities* (RIGA) initiative at the United Nations Food and Agriculture Organisation (FAO). The RIGA team has made an effort to clean and homogenise raw household survey data from 18 low and middle-income countries to construct a comprehensive database of household surveys suitable for cross-country comparisons.[4] Many of these are Living Standard Measurement Study (LSMS) surveys, designed by the World Bank. Comparable variables were generated by the RIGA team for income sources, asset holdings, employment forms, and specialisation patterns among rural households. The household survey data used in the DEVPEM applications (either the raw data or data processed by the RIGA team) are from the Bangladeshi Household Income-Expenditure Survey (2000), the Ghanaian Living Standard Survey (1998), the Guatemalan National Survey of Living Conditions (2000), the Second Malawian Integrated Household Survey (2004), the Nicaraguan Living Standard Measurement Survey (2005), and the Vietnamese Household Living Standard Survey (2002).

4. Davis *et al.* (2010) and Winters *et al.* (2009) describe the RIGA database and present detailed insights on asset holdings and income sources among rural households, based on these data. Further information is available at *www.fao.org/economic/riga*.

Henceforth, we refer to these as the "RIGA data". Besides these data from the RIGA database, FAOSTAT was used as a complementary data source for information on aggregate production and consumption of agricultural goods.

The type of income-generating activities that a rural household chooses to engage in is determined by a range of factors, including such fundamental ones as agro-climatic zone and soil quality. But given the agricultural potential of a given area, agricultural (and non-agricultural) activities are shaped by access to production factors and intermediate inputs, agricultural technology, and the functioning of input and output markets. Table 1 shows that agriculture's share of rural household income ranges from 77% in Malawi down to 50% or less in Guatemala and Bangladesh.[5] Among the agricultural income sources (defined as crops, livestock, and agricultural wage employment), crop growing is relatively important in Malawi, Ghana, and Viet Nam, livestock in Nicaragua and Viet Nam, and agricultural wage labour in Guatemala, Nicaragua, and Bangladesh. Non-agricultural income sources essentially consist of non-agricultural employment income (wage or self-employment).

These differences in income sources suggest that agricultural policies will have differential welfare impacts in the six countries. First, agricultural policies are likely to have the strongest effects in places where households derive a large share of their total income from agriculture. But the effects of any given agricultural policy will also depend on the type of agricultural activity that households are primarily engaged in. If the majority of the rural population are labourers and few are own farmers, then, for example, input subsidies are likely to benefit them relatively little. If food crops are grown by relatively poor farmers and cash crops are grown by better-off larger farmers, then cash-crop price support is likely to have small effects on rural poverty.

Table 1. Household income shares among rural households in DEVPEM countries

	Malawi	Ghana	Guatemala	Nicaragua	Viet Nam	Bangladesh
Crops	56.1	55.0	27.6	21.1	41.5	15.5
Livestock	9.4	4.4	2.6	14.3	14.8	1.2
Agricultural wage employment	11.4	1.4	19.9	21.4	5.9	20.2
Agriculture, total	*76.9*	*60.8*	*50.1*	*56.8*	*62.2*	*36.9*
Non-agricultural wage employment	7.4	9.6	20.2	21.3	9.2	19.9
Non-agricultural self-employment	8.7	20.5	12.4	11.1	21.2	16.4
Transfers	6.6	8.5	16.9	6.1	7.0	13.4
Other income sources	0.3	0.5	0.5	4.6	0.3	13.4
Non-agricultural sources, total	*23.0*	*39.1*	*50.0*	*43.1*	*37.7*	*63.1*

Source: Davis *et al.* (2010), Table 2.

5. The income shares are based on Davis *et al.* (2010), using the RIGA database. Winters *et al.* (2009), also using the RIGA database, report an agricultural income share of 62% for Bangladesh.

Despite the heterogeneity among the six countries, we made few country-specific assumptions in the country applications of DEVPEM. The reason for this is to ensure maximum comparability. The differences all lie in the activities that the households participate in, and the corresponding production functions.

There are six agricultural commodities defined for each country model. Commodities were chosen to represent the most important ones in terms of rural household consumption and overall importance to the agricultural sector of the country. We identified these by studying production and consumption patterns in the RIGA datasets and using aggregate values on production and consumption from the FAOSTAT database. While the commodities may differ from country to country, they always include a sample of staple crops, cash crops, permanent crops, and a livestock account. The specific commodities for each country are reported in Table 2. All output in each country is assigned to one of the six defined categories. While the factor and input categories are common across all six country models, the production functions are different for each country and for each household group in each country.

Table 2. Agricultural commodities defined for each country

	(1)	(2)	(3)	(4)	(5)	(6)
Malawi	Maize	Rice	Other annual food crops	Tobacco	Permanent crops	Livestock
Ghana	Tubers	Other annual food crops	Plantains	Cocoa	Other permanent crops	Livestock
Nicaragua	Maize	Beans	Other annual food crops	Cash crops	Permanent food crops	Livestock
Guatemala	Maize	Other annual food crops	Annual cash crops	Coffee	Other permanent crops	Livestock
Viet Nam	Rice	Other food crops	Coffee	Other cash crops	Other permanent crops	Livestock
Bangladesh	Rice	Other food staples	Other annual food crops	Cash crops	Other permanent crops	Livestock

Household categories

We specify six distinct household groups with household-specific activities, incomes and expenditures. The six household groups include only the rural population, the urban sector being treated as exogenous in DEVPEM. The purpose of distinguishing between household groups is to capture heterogeneity in the constraints that households face that are likely to affect their response to external shocks.

It is important to rely on exogenous constraints when defining the household groups. This is of particular importance in DEVPEM, which treats household market participation as an endogenous outcome. This implies that information on sales or purchases cannot be used to define household groups. We define the household groups based on *access to land* and *remoteness to markets*. The six household groups are: 1) non-farm households, 2) small remote farmers, 3) small non-remote farmers, 4) medium remote farmers, 5) medium non-remote farmers, and 6) large farmers. These can be thought of as representative households for different segments of the rural population. The two remote household groups face higher transaction costs than the non-remote groups, and they are assumed to be isolated from staple food markets. Local markets often exist even in the most remote communities, but they operate in isolation from the rest of the world, and the prices on those markets reflect endogenous prices for the whole remote community. In that sense, the remote households in the model are not only representative of households in pure autarky, but also of households who buy and sell on local, isolated markets. They are pure subsistence households in the model baseline, but their market participation status may change.

Since land ownership differs greatly between countries, a farmer with, say, one hectare of cultivated land may be considered small in one country and fairly large in another. Thus rather than defining category cut-off points as particular areas, we defined them as percentiles of the distributions, common for all six countries. This treatment of household categories has the advantage of providing a basis for cross-country comparison. Table 3 illustrates the categorisation of household groups in DEVPEM.

Table 3. Household categorisation in DEVPEM

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="4">Cultivated land</td></tr>
<tr><td>None</td><td>30% least endowed farmers</td><td>Rest of the distribution</td><td>15% most endowed farmers</td></tr>
<tr><td rowspan="2">Distance to markets</td><td>25% most remote farmers</td><td rowspan="2">[1] Non–farm households</td><td>[2] Small remote farm households</td><td>[4] Medium-sized remote farm households</td><td rowspan="2">[6] Large farm households</td></tr>
<tr><td>Rest of the distribution</td><td>[3] Small non-remote farmers</td><td>[5] Medium-sized non-remote farm households</td></tr>
</table>

Access to land was defined not in terms of land ownership but in terms of cultivated land. Several observations justify this choice. In some countries access to land may be granted through traditional rights rather than "formal" land ownership, such that households cultivating land without a formal title should still be considered "owners" of that plot. Furthermore, their access to land is likely to be relatively secure in the short run, which is what DEVPEM is designed to simulate. Finally, rented or sharecropped land is rare in all of our surveys, which minimises the potential error induced by our assumption. The cut-off points on the cultivated land distribution (30% at the bottom and 15% at the top) were chosen to reflect the asymmetry of the land distribution (many small farmers, few large ones). The non-farm households are landless but may still be engaged in agriculture as labourers.

To define remoteness, we computed an index at the community level using distances to basic services or administrative centres (roads, buses, telephones, hospitals, schools, regional capitals, etc., variables depending on availability in each country survey). The index was computed as the z-score of all distances available in the survey, at the community level. We considered as remote those households living in the 25% most remote communities according to this measure. Large farmers were not considered to be remote because we assume that their scale and the size of their assets would allow them to overcome transaction costs no matter where they might be situated. They are also unlikely to locate all their agricultural production in the remote communities, because of the volumes involved. It is well-established that land ownership is strongly correlated with market participation (Barrett and Dorosh, 1996), therefore assuming that all large farmers are well connected to markets is, in our opinion, a reasonable one. This treatment of transaction costs is essentially a hybrid of the way in which transaction costs are modelled in agricultural household models (de Janvry *et al.*, 1991) and in village models (Taylor and Adelman, 2003). The former generally assume that transaction costs are household specific, while the latter emphasise that households located in remote regions may have in common high transaction costs. In DEVPEM, small and medium-sized farms in remote areas are considered to be subsistence producers with respect to food crops in all six countries.

Since household groups are not defined as quintiles, some groups are relatively small while others are larger. As shown in Table 4, the biggest household groups are the *small non-remote* and *medium-sized non-remote* farm households, on average accounting for 38% and 27%, respectively, of all rural households. Medium-sized remote and large farm households account each account for on average 10%, while non-farm households and small remote households represent, are on average the smallest groups, representing less than 10% each. Hence, if policy impacts were distributed proportionately, the group of small non-remote households would on average get the biggest share of the benefits.

Farm size and proximity to markets are in general both positively related to household income. In four of the six DEVPEM countries, small remote farm households have lowest average income. Hence, non-farm households are not necessarily the poorest households; in four out six cases, however, they have the second-to-lowest income. In five out of six cases, large farmers have the highest average income. Viet Nam is an exception, where the non-farm household group is actually the wealthiest while large farmers have the lowest average income, according to the RIGA database.

Table 4. Relative size of household groups and average income

		Non-farm	Small remote	Small non-remote	Medium remote	Medium non-remote	Large farm
Ghana	Share of households	8%	4%	29%	11%	34%	13%
	Income index	100	88	103	117	109	156
Malawi	Share of households	3%	6%	25%	14%	38%	14%
	Income index	100	100	129	144	153	205
Guatemala	Share of households	7%	9%	50%	6%	20%	8%
	Income index	100	84	112	79	99	117
Nicaragua	Share of households	6%	10%	48%	9%	19%	7%
	Income index	100	79	120	100	118	127
Bangladesh	Share of households	13%	11%	42%	6%	20%	8%
	Income index	100	84	100	99	121	139
Viet Nam	Share of households	7%	5%	31%	12%	33%	12%
	Income index	100	50	79	34	68	33
Average	*Share of households*	*7%*	*8%*	*38%*	*10%*	*27%*	*10%*
	Income index	*100*	*81*	*107*	*96*	*111*	*130*

Note: The income index is 100 for non-farm households in each country. Source: The income index is based on total household income estimates from the RIGA database, *www.fao.org/economic/riga*.

By assumption, the two household groups defined as remote are self-sufficient in food crops. This means that, as a group, these households do not trade with the rest of the economy, even though they may trade with each other locally, at prices that are disconnected with the rest of the economy. In reality, even remote households participate in trade to some extent even with the rest of the economy. The volumes are likely to be small, however, and for simulation purposes we assume that their initial trading status with the rest of the economy is zero. Except for this assumption, we have let the actual data that underlie the SAMs reveal the trading status of household groups in each country.

Table 5 shows that, as a whole, the group of small farm households are net buyers of food crops in the four low-income countries but net sellers in Guatemala and Nicaragua, whereas medium and large farmers are net sellers of food crops in all six countries. Each household group in DEVPEM is modelled as one representative household. Hence, even though there are net buyers and net sellers of food in all household groups in the household data, when each group is treated as an aggregate household, small non-remote farmers are net buyers in four of the six countries and all medium non-remote and large farmers are net sellers of food.

Table 5. Trading status in food crops by DEVPEM household group

	Small remote farms	Small farms	Medium-sized remote farms	Medium-sized farms	Large farms
Malawi	0	-	0	+	+
Ghana	0	-	0	+	+
Guatemala	0	+	0	+	+
Nicaragua	0	+	0	+	+
Viet Nam	0	-	0	+	+
Bangladesh	0	-	0	+	+

Note: Trading status: net-seller (+), net-buyer (-), or self-sufficient (0). Remote households are self-sufficient by assumption.

Source: Authors' estimates based on the RIGA database.

The social accounting matrix (SAM)

DEVPEM consists of a set of variables (for which we have observations) and a set of relationships among variables, defined by equations with parameters (for most of which we do not have observations). In order to make the model operational and tractable, we must calibrate it, that is, find the missing parameter values, using actual production and consumption data for each country for which the model is applied. The aim of calibration procedures is to find parameter values such that the observed data represent a solution to the model. In other words, calibration consists of plugging in the observed variable values into the equations of our model to "reverse-compute" the parameter values which would have led to those observed variable values as the equilibrium solution. It is, in a sense, the mirror operation to simulations, which rely on the fixed parameter values to estimate the values of variables.

Our calibration procedure is based on a social accounting matrix (SAM) for each of the six countries. A SAM provides a picture of all flows of money and goods in an economy in matrix form, where rows represent the incomes of economic actors and columns represent expenditures. Hence, row and column totals must be equal. An advantage of using a SAM is that, by construction, all cash constraints and market clearing conditions are satisfied for all accounts in the matrix, which is consistent with general equilibrium theory. This is why computable general equilibrium (CGE) practitioners often parameterise models using SAMs.

Table 6 provides the general structure of the type of SAM used to calibrate the DEVPEM model for each of the six countries. The SAM is a matrix of values rather than quantities, but without loss of generality one can set all initial prices and rents to unity, thus implicitly converting the matrix into money-metric quantity units. Prices and rents are determined by this assumption, such that all other variables of the model appear in the SAM: quantities produced, consumed, used as factors, imported and exported. Sums along rows or columns provide us with total incomes and expenditures, total supplies and demands, all of which match to make markets clear. Each country SAM has the same structure, even if specific activities and goods differ between countries. Keeping the structure the same for each country facilitates comparability across countries and simplifies extensions of the model, with applications on additional countries.

Table 6. General structure of a SAM used to calibrate the DEVPEM model

	Expenditures					
Incomes	**Households**	**Activities for each household**	**Goods *i***	**Factors *k***	**Rest of World**	**Totals**
Households				Factor Endowments	Exogenous income	*Total Income*
Activities			Domestic production (maps activities with the goods they produce)			*Total Production Value*
Goods *j*	Household Consumption	Intermediate inputs			Exports of goods	*Total demand for goods*
Factors *k*		Factor demands			Exports of tradable factors	*Total factor demand*
Rest of World			Imports of goods	Imports of tradable factors		*Total imports*
TOTALS	*Total Expenditures*	*Total Production Value*	*Total supply of goods*	*Total supply of factors*	*Total exports*	

Aggregate production and consumption values for the social accounting matrices

Each country SAM contains values for incomes and expenditures for each household group. Incomes are in the form of returns to factor endowments (including household labour) and exogenous income. Expenditures include consumption and costs of inputs in farm production.

The aggregate value of production for each agricultural commodity is based on data on quantity and producer prices from FAOSTAT. The RIGA data were used to estimate, for each country and each product category, the share of production stemming from each household group. Thus the total value of production (*VP*) of good *g* for household group *h* is given by:

$$VP_{g,h} = p_g Q_g \times PS_{g,h} \qquad \left(\textstyle\sum_h PS_{g,h} = 1\ \forall g \in G, g \neq m\right) \qquad (16)$$

where *p* and *Q* denote price and quantity taken from FAOSTAT and *PS* denotes the household production share, estimated from the RIGA data. *PS* equals zero for rural non-farm households and for urban households. Good *m* is a composite non-agricultural "market good", excluded from the set of goods *G* in the above expression.

The total value of consumption for each household group was defined analogously to the values of production, using aggregate information from FAOSTAT. The consumption shares for each household group, including rural non-farm and urban households, were estimated using RIGA data. The total value of consumption (*VC*) of good g for household group h is given by:

$$VC_{g,h} = p_g Q_g \times CS_{g,h} \qquad \left(\sum_h CS_{g,h} = 1 \;\forall g \in G, g \neq m\right) \tag{17}$$

where $CS_{g,h}$ denotes the share of good g consumed by household group h. To estimate the value of consumption of non-agricultural products ("market goods"), we assumed that total household income (Y_h) equals total household expenditure and that non-agricultural consumption is the difference between household income and agricultural consumption. Thus, if $VC_{m,h}$ denotes the total value of consumption of "market goods" (m) for household group h, we assume:

$$VC_{m,h} = Y_h - \sum_{g,g\neq m} VC_{g,h} \tag{18}$$

The estimated production and consumption shares, for each household group and each country, are provided in Annex 2.

Model parameters

Household preferences

For consumer preferences, the model is set up to work with a linear expenditure system (LES), which is the most frequently used system in empirical estimation of consumer demand (Sadoulet and de Janvry, 1995). In the applications of the model in this study, however, the level of incompressible consumption is set to zero, which is tantamount to assuming a Cobb-Douglas functional form. Under the assumption of Cobb-Douglas preferences, the relevant parameters can be estimated from data on household expenditure on each item defined in the model. The exponents (α) in the consumption function are derived from household expenditure shares. For each good g and for each household group h these expenditure shares were defined as the value of the consumption of that good divided by total income (superscript e for expenditure):

$$s^e_{g,h} = \frac{VC_{g,h}}{Y_h} \tag{19}$$

These expenditure shares are reported in Annex 2.

Production technology

Household farm production technology is also assumed to be characterised by Cobb-Douglas specification. Analogous to Cobb-Douglas consumer preferences, the relevant parameters can be estimated using information on costs of each input in the production of each good.

The value of each input used in farm production was defined based on the assumption of zero economic profit. Under this assumption the total value of production (*VP*) equals the total cost of inputs (including implicit costs of owned factors of production). There are five inputs defined in the production of each good: own labour, hired labour, physical capital, land, and intermediate inputs (such as seeds and fertiliser). Let $VI_{f,g,h}$ denote the value of input f in the production of good g by household group h. Then:

$$VI_{f,g,h} = VP_{g,h} \times s^p_{f,g,h} \qquad \left(\sum_{f\in F} s^p_{f,g,h} = 1 \;\forall g \in G, g \neq m, \forall h \in H\right) \tag{20}$$

where $s^{p}_{f,g,h}$ denotes the share of factor f in production of good g (superscript p for production). Under the assumption of constant returns to scale Cobb-Douglas technology, the factor shares s^{p} provide the β parameters for the production functions for each good.[6] Factor shares are provided in Annex 2.

Land supply

As described in Section 2, DEVPEM uses a specification of an imperfect land supply with a three-tiered CET structure that is similar to that of the OECD PEM model (OECD, 2005). A one-tiered CET function can be calibrated simply with the knowledge of the own-price elasticity of land supply, and of the land allocation between different activities. For our three-tiered function, however, we need three price elasticity estimates of land supply, as well as the land allocations at each level. We follow the method of the PEM model to derive the elasticity of land transformation at each level.

The elasticity of land transformation at the highest "nest", which distinguishes between permanent cash crop growing and all other land uses, is derived as:

$$\sigma_1 = \frac{\varepsilon_{cc}}{(1-sr_c)} \qquad (21)$$

where ε_{cc} denotes the own-price elasticity of land supply to permanent cash crops and sr_c is the share of land allocated to such crops. At the second level, the elasticity is defined as:

$$\sigma_2 = \frac{\overline{\varepsilon_{ii}}+2\overline{\varepsilon_{ij}}-\sigma_1(sr_3/sr_2-sr_3)}{1-sr_3/sr_2} \qquad (22)$$

ε_{ii} denoting own-price elasticity of land supply for any item i in the second nest, εij cross price elasticity of supply between crop i and j in the nest, and sr_2 and sr_3 are the shares of land allocated to the second and third nest, respectively. Bars over elasticity denote averages. The third elasticity estimate is given by:

$$\sigma_3 = \overline{\varepsilon_{ii}} - \overline{\varepsilon_{ij}} \qquad (23)$$

i and j referring to items in the third nest. For a detailed derivation of these expressions, see OECD (2005). The challenge with PEM of finding country-specific land supply elasticity estimates is even greater for DEVPEM, which is designed for low-income countries, in which reliable data tend to be relatively scarce. To the best of our knowledge, there have not been any attempts to estimate land supply elasticity in any of our target countries. Since we lack the data to get such elasticity estimates, we use the same values as in the PEM model (OECD, 2005). In particular, for every country we

6. The estimation of the factor shares involved regression analysis based on RIGA data and differed in exact approach from country to country, depending on data availability on input use. The principle for obtaining the five factor shares (that sum to 1) was to regress net agricultural income on variables representing labour, physical capital, and land, used in production among farm households that are specialised in one good. The sum of shares for these three inputs was restricted to equal the ratio of net income to gross agricultural income. The input shares for hired labour and intermediate inputs were defined by splitting the residual, which is the difference between gross and net income, divided by gross income.

assume that the own-price elasticity of land supply to permanent crops, ε_{cc}, is 0.1; [7] the own-price elasticity of land supply to all field crops (ε_{ii}) is 0.4; and that the cross-price elasticity of land supply between any two field-crops (ε_{ij}) is -0.15. Thus, σ_3 is constant and equals 0.55 for all households in all six countries. The other two elasticities, σ_1 and σ_2, vary by household group and country, with averages of -0.13 and -1.94, respectively.

Transaction costs

Including transaction costs in the model requires parameters, which are difficult to estimate with precision. There is only a small body of empirical literature on transaction cost estimation in rural areas of developing countries. Renkow *et al.* (2004), in a study on Kenya, find that "on average the ad valorem tax equivalent of the fixed transactions costs in the sample is 15.5%". Cadot *et al.* (2006), use Malagasy data and define transaction costs as the revenues foregone due to non-participation in markets. They use switching regression estimates to calculate "the opportunity cost of not switching" for the "marginal" farmer, and evaluate this cost at a surprisingly high level: "more than one year of the typical subsistence farmer's output valued at market prices". Lacking authoritative data on transaction costs, we set the value of transaction costs to 10% of all transactions made in remote areas of all of our studied countries. This value is not in disagreement with previous literature, and has the advantage of allowing cross-country comparison and systematic sensitivity analysis. Transaction costs for non-remote households are set to zero in the model.

3. Policy simulation setup and impact measures

In the agricultural policy simulations, we analyse the effects of five different policies in each of the six countries included in the study. Three of the policies are *market interventions*, in the form of market price support, a production subsidy, and an input subsidy; one of them is a *social transfer*, in the form of an unconditional cash transfer; and one is a *public-good investment* aimed at lowering rural transaction costs and facilitating access to markets. We are interested primarily in finding out about each policy's ability to increase welfare of rural households, but also how costs and benefits are distributed for each policy, and how cost efficient each policy is in terms of raising welfare of the targeted people for every dollar spent on the policy. This section briefly describes the character of the policies that are simulated and how we measure the welfare effects from them. The results of the simulations are discussed and analysed separately in the OECD report "Modelling the Distributional Impacts of Agricultural Policies in Developing Countries: The Development Policy Evaluation Model (DEVPEM)" (OECD *OECD Food, Agriculture and Fisheries Working Paper* N°51).

Policy design and implementation

The market price support (MPS) and production subsidy (PS) are both targeted at agricultural commodity markets, the main difference between the two policies being that the former affects consumer prices while the latter does not. Production subsidies are rarely implemented in developing countries, as they necessitate the use of scarce

7. In the countries producing rice (Malawi, Bangladesh, and Viet Nam), land use for rice is defined as a third item in the first nest. In these cases, the own-price elasticity of land supply for rice is assumed to equal that of permanent cash crops, -0.1.

budgetary resources. However, they provide an instructive comparison with MPS policies because of this basic difference in effect. Input subsidy (IS) policies intervene in markets in which farmers are buyers and consumers do not participate, such as the markets for seeds and fertiliser. Common for all policy experiments is the assumption that the urban economy (urban consumers and taxpayers) bears all the explicit costs of the policies in terms of taxes. Some of the policies also imply implicit costs to the urban economy in terms of consumer surplus losses due to higher commodity prices.

Market price support

The MPS policy acts as a price floor, or a regulated minimum price, for the targeted commodity. It raises the price above the world market price for farmers and rural consumers, as well as for urban consumers. In the rural economy, farm households gain as producers and lose as consumers due to the MPS, their net gain depending on their production surplus. As long as they produce more than they consume they are likely to gain from the policy. We analyse the effects of market price support for three agricultural commodities: the main food crop, the main cash crop, and livestock products. We assume in the model that rural households consume some of the food crops and some of the livestock products. The main cash crop, however, is produced for 'export' only, either for the world market of for the urban market. The experiment consists of raising the domestic price 10% above the world market price of one commodity at the time. This price change is small enough to assume that the model parameters for consumer preferences and production technology remain valid, yet large enough to cause noticeable behavioural adjustments among households.

The effects of market price support will be different depending on whether the rural economy exports or imports the targeted commodity and whether the country as a whole is a net-importer or a net-exporter of the good. Let us consider first the case where the country is a net exporter of the targeted crop. At the world market price, P_w, the rural economy has an excess supply $ES(P_w)$, as depicted in the right graph in Figure 5a. Since urban demand is only $Qdu(P_w)$ at the world price, the country exports $ES(P_w) - Qdu(P_w)$. If a price floor $\underline{P}$ is implemented, the rural economy only demands $Qdr(\underline{P})$, the urban economy only $Qdu(\underline{P})$, while production increases to $Qs(\underline{P})$. The excess supply not purchased in the urban market, $ES(\underline{P}) - Qdu(\underline{P})$, will have to be bought by the government and exported at price P_w. For urban agents, there are both taxpayer costs and consumer surplus losses due to the policy. The taxpayer cost amounts to the quantity exported times the unit price support, represented by rectangle *bcd* in Figure 5a. Due to lower consumption, urban consumers lose consumer surplus equal to area *ab*. The urban cost of the policy is (with a linear demand curve, as assumed in Figure 5a):

$$UCP = \left[ES(\underline{P}) - Qdu(\underline{P})\right] \times \left(\underline{P} - P_w\right) + \left[Qdu(P_w) - \frac{Qdu(P_w) - Qdu(\underline{P})}{2}\right] \times (\underline{P} - P_w) \quad (24)$$

where the first term corresponds to area *bcd* and the second term to area *ab*.[8]

If the country is a net importer of the targeted food crop before and after the price policy is implemented, the outcome will be somewhat different. Instead of buying a surplus of production, the government can now keep the domestic price up by an import

8. If an estimate of the urban price elasticity of demand is available, the change in urban quantity demanded, $Qdu(Pw) - Qdu(\underline{P})$, can be calculated as $\Delta Qdu = \varepsilon \times \Delta P/Pw \times Qdu(Pw)$, where ε denotes the urban price elasticity of demand for the good.

tariff. Figure 5b illustrates this case. At the world market price P_w the country is a net importer of quantity $Qdu(P_w) - ES(P_w)$. A price floor at $\underline{P}$, implemented by an import tariff, decreases urban quantity demanded to $Qdu(\underline{P})$ and rural quantity demanded to $Qdr(\underline{P})$, while increasing the excess supply from the rural economy to $ES(\underline{P})$. This shrinks the imported quantity down to $Qdu(\underline{P}) - ES(\underline{P})$. The urban cost of this policy is made up by the net of the loss in consumer surplus (rectangle *abcd* in Figure 5b) and the tariff revenues raised by the government (rectangle *c*). This net effect corresponds to areas *abd* in Figure 5b, such that:

$$UCP = \left[ES(\underline{P}) + \frac{Qdu(P_w) - Qdu(\underline{P})}{2}\right] \times (\underline{P} - P_w) \quad (25)$$

If, however, urban consumers are unable to benefit from the tariff revenues, their cost corresponds to area *abcd*, or:

$$UCP = \left[Qdu(\underline{P}) + \frac{Qdu(P_w) - Qdu(\underline{P})}{2}\right] \times (\underline{P} - P_w) \quad (25')$$

If the country is a net importer with an *excess demand* in the rural economy, the effects will be a bit different in the urban economy. The scenario is shown in Figure 5c. At world market price P_w, the country is importing $ED(P_w) + Qdu(P_w)$, *ED* denoting rural excess demand. The market price support policy raises the domestic price to $\underline{P}$. Similar to the previous case, this can be implemented by an import tariff. The effect on the urban economy is two-fold: there is a loss in consumer surplus due to the decrease in quantity demanded, from $Qdu(P_w)$ to $Qdu(\underline{P})$, and there are tariff revenues equal to the quantity imported times the tariff. The loss in urban consumer surplus corresponds to the area *abcd* in Figure 5c. The ex-post quantity imported is the sum of $ED(\underline{P})$ and $Qdu(\underline{P})$; tariff revenues are therefore equal to areas *a* plus *abc* (not only *abc*). The net urban cost of policy consists of areas *d* – *a*, which could be positive or negative, depending on how the two demand curves are drawn. We can express the cost as:

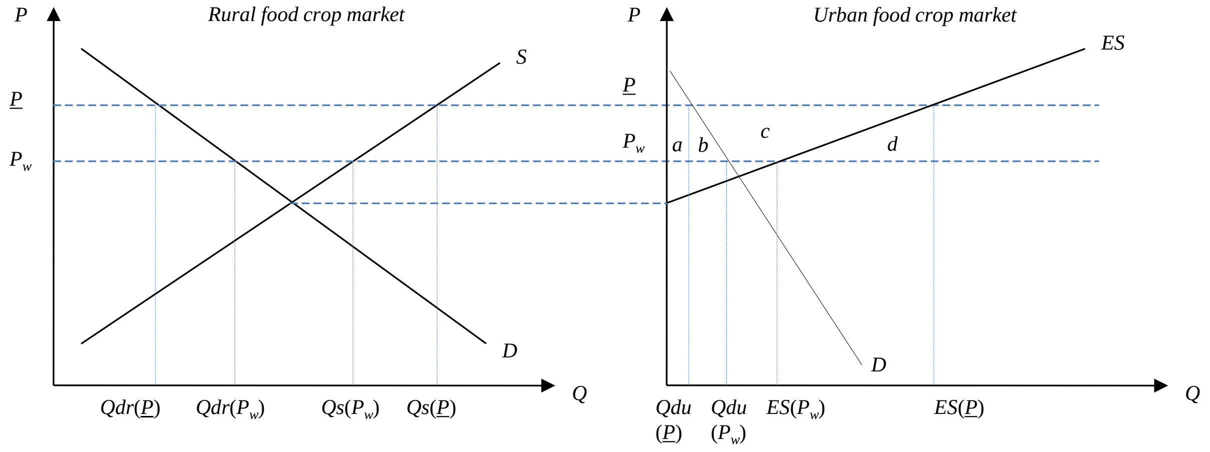
$$UCP = \left[\frac{Qdu(P_w) - Qdu(\underline{P})}{2} - ED(\underline{P})\right] \times (\underline{P} - P_w) \quad (26)$$

But again, if urban consumers find themselves unable to benefit from the tariff revenues, their cost is represented by area *abcd*, such that:

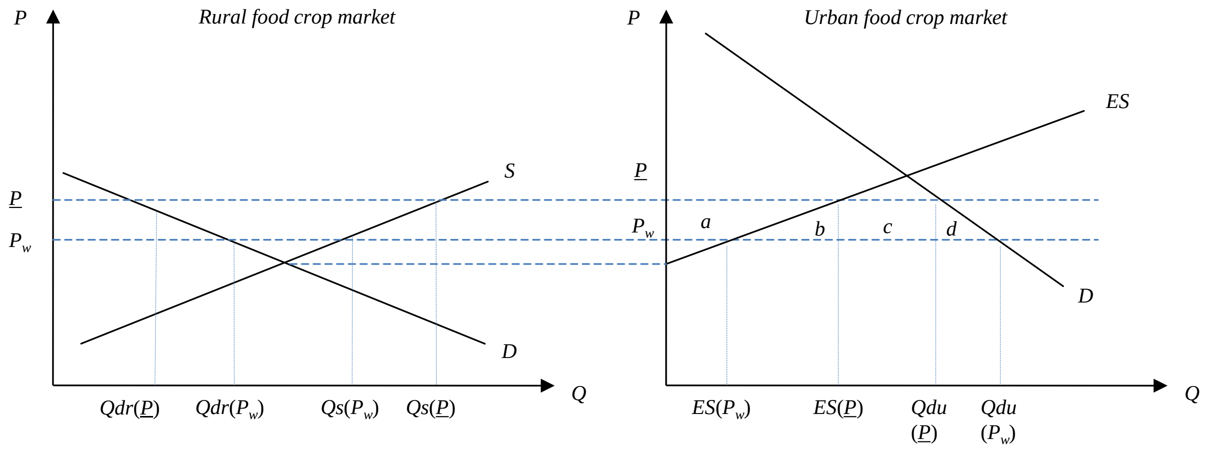
$$UCP = \left[Qdu(\underline{P}) + \frac{Qdu(P_w) - Qdu(\underline{P})}{2}\right] \times (\underline{P} - P_w) \quad (26')$$

Figure 5. Effects of a price floor under three different trading situations

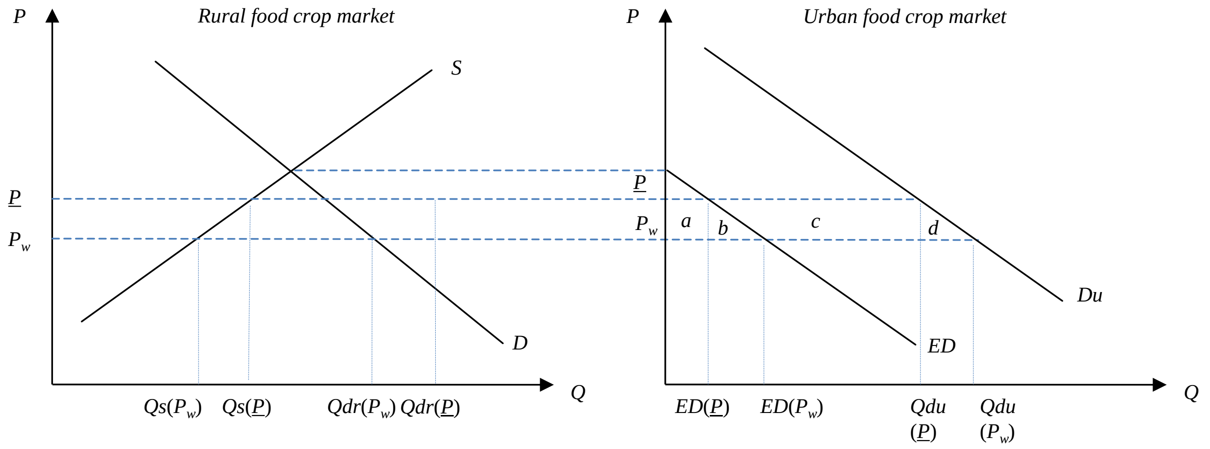
(a) Net-exporting country (with rural excess supply)



(b) Net-importing country (with rural excess supply)



(c) Net-importing country, with rural excess demand



Production subsidy

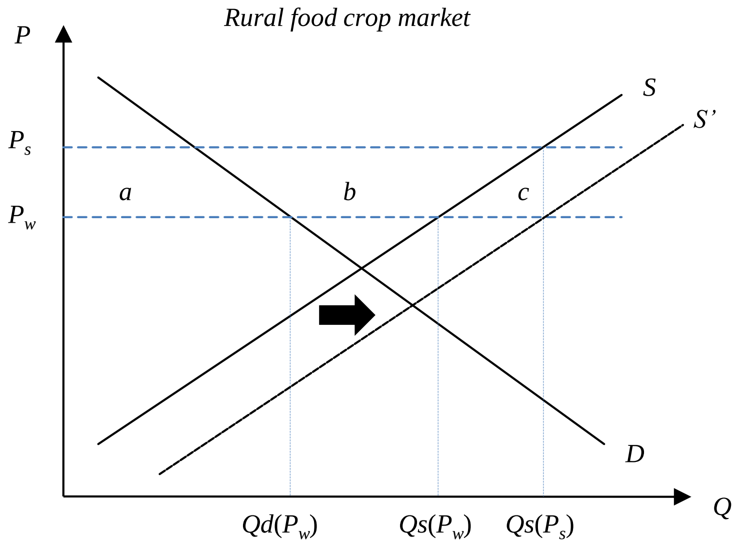
In contrast with an MPS policy, a production subsidy does not affect consumers in terms of higher prices. This follows from the assumption of exogenous output prices. The subsidy, as implemented here, gives the farm household a mark-up on the world market price for each unit of the commodity it produces and sells. To the extent that the farm household consumes the targeted commodity, it is able to buy it in the market at the world market price. This means that, in the rural economy, the quantity supplied of the good increases due to the higher seller price, but the quantity demanded remains unchanged. Consequently, the rural excess supply of the commodity increases, although less than under an MPS policy.

Figure 6 depicts the rural market for a food crop. At world price P_w, the rural economy demands $Qd(P_w)$ and produces $Qs(P_w)$, which, in this case, makes it a net exporter to the rest of the world. If the government offers a production subsidy, the farmer receives P_s for each unit of production sold (subscript *s* for selling price). This induces an increase in quantity supplied to $Qs(P_s)$. The deficiency payment does not affect the consumer price in the economy, hence quantity demanded remains unchanged at $Qd(P_w)$. The tax needed to finance the policy amounts to the domestic quantity produced times the subsidy amount per unit of output. As with an MPS policy, the domestic surplus of the commodity will be exported at the world market price. The urban cost of the policy (*UCP*) is the price support, $P_s – P_w$, times total quantity produced:

$$UCP = Qs(P_s) \times (P_s - P_w) \qquad (27)$$

which corresponds to the area defined by rectangle *abc* in Figure 6.

Figure 6. The effects of a production subsidy



As with the MPS experiments, we analyse the effects of a production subsidy for the main food crop, main cash crop, and for livestock products. Since rural households are assumed not to consume any of the cash crops, the effects on the rural economy of an MPS and PS are identical for cash crops. As in the MPS experiments, we assume that the subsidy consists of a 10% mark-up on the world market price.

Input subsidy

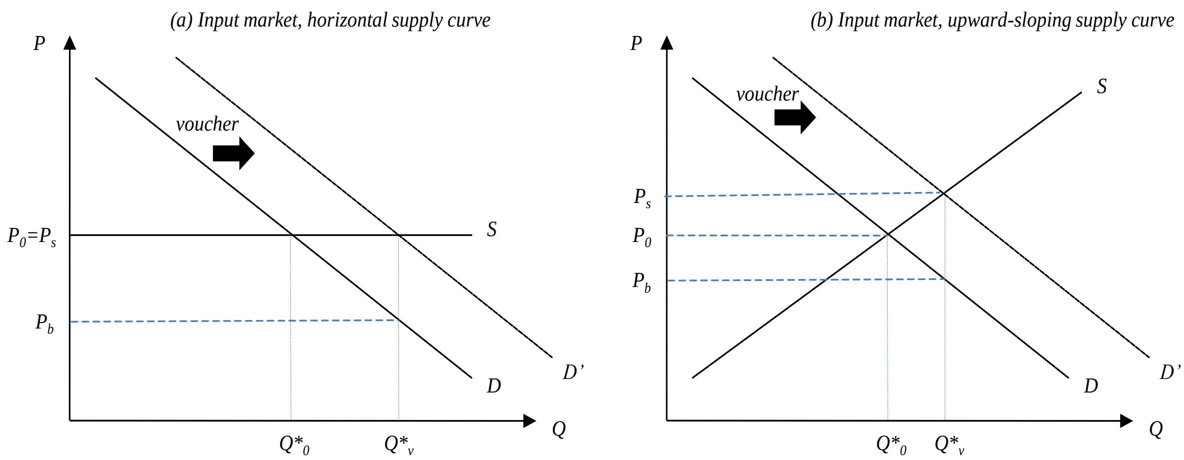
An input subsidy enables farm households to buy intermediate inputs at a lower price than the market price. The input subsidy can be implemented either in form of a voucher to buyers (farmers) or as a distribution subsidy to sellers of the input. In theory, the cost as well as the distribution of benefits of the policy is the same in both cases. How the benefits of a subsidy (or the costs of a tax) are distributed between buyers and sellers in the market are determined solely by the price elasticity of supply and demand. In our simulations, we assume that the policy is designed as giving vouchers to farmers. We study two scenarios: one in which the input supply curve is horizontal and one in which it is upward sloping.

A voucher given to farmers, allowing them to buy fertiliser at 10% (or 10 currency units) below the market price, implies an outward-shift of the input demand curve, as depicted in Figure 7a. This raises the equilibrium quantity from Q^*_0 to Q^*_v. Given the perfectly elastic supply, the buyer price (P_b) falls with the entire amount of the voucher, while the seller price remains unchanged at P_0. This means that the whole benefit accrues to the buyer (the farmer) and that there is no leakage of benefits to the input supplier. The cost of the policy is the value of the voucher (v) multiplied by the new equilibrium quantity:[9]

$$UCP = Q_v^* \times v \tag{28}$$

With an upward-sloping supply curve, the outcome is different in terms of benefit distribution and slightly different in terms of the ex-post equilibrium quantity compared with the case of a horizontal supply curve. The buyer price now falls with less than the entire voucher amount, while the seller price increases from P_0 to P_s. The cost of the policy is expressed as in the previous case, but since the equilibrium quantity increases less than under perfectly elastic supply, the cost of the policy will be slightly lower.

Figure 7. An input subsidy under horizontal and upward-sloping supply curve.



9. If the subsidy is *ad valorem* and not a lump sum, then we can express the cost as $UCP = Q^*v \times v \times P0$, where v denotes the subsidy in per cent.

Cash transfers and public-good investments

The way we simulate the cash transfer in this study is trivial and essentially used only as a benchmark policy experiment. Every farm household group receives a small cash transfer equal to one per cent of the household income.

Investments in public goods can take many forms, and the type that we consider here is an infrastructure-type of investment that alleviates transaction costs for remote households. This does not have to be related to transportation. It could, for example, be an investment in a mobile telecommunication network, connecting people living in remote areas to people in towns and cities, allowing them to receive information about current prices of crop or livestock products or current labour demands in different regions. The policy in our experiment is assumed to be designed in a way that, after the investment, remote households face the same set of effective prices as other (non-remote) households. This policy only affects two of the household groups and we cannot say anything specific about the cost of the policy or its relative efficiency.

Measuring rural household welfare impacts

When analysing the welfare impacts of different policies on rural households, it is important to distinguish nominal income (measured in currency units) from real income (measured in purchasing power). It is also important to contrast the welfare effects before and after households have been able to adjust. Farm households may be unable to respond immediately to a relative price change in the agricultural commodity market. Only with a time lag may households be able to adjust their agricultural production and consumption patterns.

The difference between nominal and real income changes, on the one hand, and pre-adjustment and post-adjustment welfare effects, on the other hand, can be illustrated with three measures: the *nominal income change*, the *immediate welfare effect*, and the *final welfare effect*. We define the change in nominal income simply as the change in monetary income due to changes in sales revenues and wage incomes. The immediate welfare change is defined here as the change in real income (purchasing power) before any behavioural responses are allowed in the economy. Hence it provides the change in real income, provided that the household produces, sells, and buys the same quantity of every commodity, and supplies the same amount of labour, as before the policy shock. Inspired by Zezza *et al.* (2008), we base our immediate welfare measure on the following expression:

$$\Delta w = \Delta p_j \left(Q_j^p - Q_j^c \right) + \Delta t \qquad (29)$$

where Δw denotes change in welfare, Δp_j change in price of good j, Q_j^p and Q_j^c quantities of good j produced and consumed, respectively, and Δt is the change in a transfer or a lump sum tax.[10] The measure is “immediate” in the sense that levels of household production and consumption are unchanged. If the price change is positive and the household is a net seller of good j, then sales revenues increase by the price change times the quantity sold. To express the change in real income Δw in percentage terms, we divide both sides of the expression in (29) by initial household income, y (assumed to equal total consumption):

10. Goods j also include intermediate inputs used in agricultural production.

$$\frac{\Delta w}{y} = \frac{\Delta p_j\left(Q_j^p - Q_j^c\right) + \Delta t}{y} \qquad (29')$$

To express (29') in terms of prices and quantities, we can replace income by total consumption expenditure ($\Sigma_i p_i Q_i$):

$$\frac{\Delta w}{\sum_i p_i Q_i^c} = \frac{\Delta p_j}{p_j}\frac{\left(p_j Q_j^p - p_j Q_j^c\right) + \Delta t}{\sum_i p_i Q_i^c} \qquad (29'')$$

Thirdly, we define the *final welfare change* (or just the *welfare change*) as the change in real income after behavioural adjustments of households. The final welfare change is a compensating-variation measure that essentially answers the question: "What is the amount of income that could be taken away from the household (or would need to be given to the household) to bring it back to the welfare level it had before the policy shock?"

As explained by Robichaud (2001), the compensating variation (CV) welfare measure for a Cobb-Douglas utility function is derived by first defining the money metric indirect utility function. Let the C-D utility function be defined by:

$$\mu(C) = \prod_{i=1}^{I} C_i^{\alpha_i} \qquad (30)$$

The derived demand function for each good *i* is:

$$C_i(P,Y) = \frac{\alpha_i Y}{P_i} \qquad (31)$$

As noted by Robichaud, the indirect utility function, $\nu(P, Y)$, is obtained by replacing the C_i in the utility function with the demand functions for each good *i*:

$$\nu(P,Y) = \prod_{i=1}^{I}\left(\frac{\alpha_i Y}{P_i}\right)^{\alpha_i} \qquad (32)$$

Solving for *Y* in (32) gives the money metric indirect utility function, $m(P, \nu)$, which is a measure of income needed to reach utility level ν, given prices *P*:

$$m(P,\nu) = \prod_{i=1}^{I}\left(\frac{P_i}{\alpha_i}\right)^{\alpha_i}\nu \qquad (33)$$

The compensating variation is given by:

$$CV = m\left[P_i^1, \nu\left(P_i^1, Y^1\right)\right] - m\left[P_i^1, \nu\left(P_i^0, Y^0\right)\right] \qquad (34)$$

where the first term is the money metric of the indirect utility at ex-post prices and income and the second term is the money metric for the initial utility level under ex-post prices. The first term answers the question: What is the amount of money required to reach the utility level you have at prices P^1 and income Y^1? The answer is, trivially, Y^1. The second term answers the question: What is the amount of money that would let you reach the utility level that you had initially, given the new prices P^1? If there has been an increase in prices and the income is unchanged, then the first term is lower than the second term, hence the CV is negative. To get the amount of money needed to compensate the individual for the price change, one needs to use the *negative* of the CV.

Simplifying the first term of (34) gives:

$$CV = Y^1 - m\left[P_i^1, v\left(P_i^0, Y^0\right)\right] \quad (34')$$

which may be the most intuitive definition of the CV. If we want to go further by expressing the CV in terms of prices and income, we can substitute (32) and (33) in (34') to get:

$$CV = Y^1 - \prod_{i=1}^{I}\left(\frac{P_i^1}{\alpha_i}\right)^{\alpha_i}\prod_{i=1}^{I}\left(\frac{\alpha_i Y^0}{P_i^0}\right)^{\alpha_i} = Y^1 - \prod_{i=1}^{I}\left(\frac{P_i^1}{P_i^0}\right)^{\alpha_i} Y_0 \quad (34'')$$

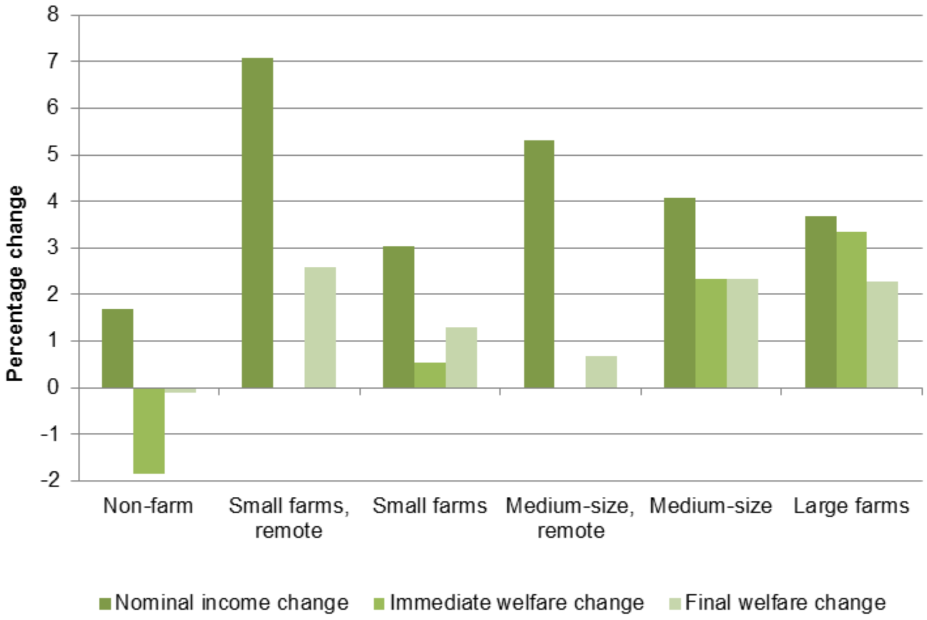
While in some cases the nominal income, immediate welfare, and final welfare measures are almost identical, they differ greatly in other cases, due to the combination of behavioural responses on the producer and consumer side as well as due to general-equilibrium linkage effects. Figure 8 illustrates the difference between the three measures by showing results from one of the stylised policy simulations for Ghana: a 10% price support for the main food crop (tubers). The nominal income change is positive for each household group, ranging from less than 2% for non-farm households to 7% for small remote households. Non-farm households gain in nominal terms due to increased wage incomes, which, in turn are a result of increased agricultural labour demand. Small remote farm households benefit the most in nominal terms in this case, since the MPS policy allows them to enter the market and sell some of their production.

As soon as we take the loss in purchasing power into account, however, and study the immediate change in real income, the welfare effect is smaller for all groups and even negative for one group. Non-farm households suffer an immediate real-income loss, due to the fact that their consumption bundle is now more expensive, yet they have not had the chance to adjust their consumption or labour supply. Remote households see no immediate welfare effect, since they are assumed to be self-sufficient in the food crop before the policy shock and they are unable to adjust in the very short run to changes in market prices. Large farmers gain almost as much in real terms as in nominal terms, reflecting the fact that their losses on the consumption side are small relative to their gains on the production side.

The final welfare effect – when households have been able to adjust – may be smaller or larger than the immediate welfare effect. Non-farm households re-arrange their consumption bundle, substituting away from the now more costly food crop, while benefitting from higher wage income, making final welfare essentially the same as the initial level. Small remote farm households have a smaller final welfare effect than the immediate welfare effect, since part of their gain is eroded by higher consumer prices. The welfare gain by large farmers is somewhat smaller than their immediate welfare gain due to increased costs of hired labour.

As a static model, with some factors of production being fixed, DEVPEM is designed to show household response and welfare impacts in the medium run, that is, after households have been able to adjust the use of variable factors of production and consumption patterns. When analysing welfare impacts of each policy, the focus is primarily on the final welfare change measure.

Figure 8. Three measures of welfare effects of a market price support policy



Policy cost efficiency

Similar to the PEM model, DEVPEM is a policy evaluation model that can be used to compare welfare implications of different agricultural policies. From a cost-benefit perspective, the most efficient policy instrument is the one best at achieving the target benefit at lowest cost. When analysing various policies in PEM, their relative efficiency can be assessed in terms of *transfer efficiency*, usually defined as:[11]

$$Transfer\ efficiency = \frac{change\ in\ farm\ net\ income}{total\ cost\ to\ taxpayers\ and\ consumers}$$

For a commercial farm with zero transaction costs, the net benefit of a given policy is simply the change in producer surplus or net farm income. This policy efficiency measure needs to be modified if the producer of the agricultural good is a household rather than a pure firm. When consuming a significant share of what they produce, agricultural households in developing countries may lose as a result of policies that raise output prices. An increase in nominal income may be more than offset by an increase in expenditures on consumption. Due to the dual role of agricultural households as producers and consumers, and due to the market linkage effects in DEMPEM, an alternative measure is needed which keeps households in the denominator separate from households in the numerator. We measure policy efficiency as the ratio of the aggregate change in rural household welfare to total urban cost of the policy:

$$Policy\ efficiency = \frac{change\ in\ rural\ household\ welfare}{urban\ cost\ of\ policy}$$

11. A detailed discussion of transfer efficiency of agricultural policies is provided by OECD (1995). The use of the transfer efficiency measure in the PEM model is discussed by Dewbre *et al.* (2001) and OECD (2001, 2005).

The numerator is the aggregate (rural economy-wide) final welfare change, based on the compensating-variation measure defined above. The denominator of the efficiency measure is the urban cost of the policy (UCP), defined above for each policy. It includes tax payments and any consumer surplus losses faced by urban households. As we noted, the magnitude of this urban cost depends not only on policy design but how much urban households consume of the targeted good, how large the production surplus is from the rural economy and whether the country is a net exporter or importer of the good.

4. Conclusion

DEVPEM was developed as a companion to the OECD's PEM as a tool for policy evaluation in less-developed countries, in which agricultural production is carried out by heterogeneous households and where market transaction costs potentially play an important role in shaping policy impacts. There are fundamental differences between the two models. In structural terms, one might view the PEM as effectively being a special case of DEVPEM, in which production is carried out not by a single aggregate or representative firm, and in which transaction costs are negligible. The dual nature of agricultural households as producers and consumers has the important implication that increases in commodity prices create both positive income and negative consumption effects in DEVPEM agricultural households. The negative welfare effect of higher consumption costs explains why market price supports for staples rank low in terms of efficiency in DEVPEM countries.

DEVPEM reflects other structural features that distinguish developing country economies from the economies of most OECD countries. For example, while production on rented land is commonplace in high-income countries, it is rare in the six countries studied here. This has the important implication that policy-induced increases in the returns to land (e.g. due to MPS or input subsidies) accrue to agricultural households in DEVPEM, whereas in PEM, a significant share of increased returns to land are capitalised in land rents paid by farmers to non-farm households. Because of the diversity of agricultural households in developing countries, the impacts of agricultural policies are also varied, often creating both winners and losers. Heterogeneous technologies, resource endowments, market access, and consumption demands also shape the aggregate impacts and efficiency of alternative policy instruments. DEVPEM was designed to highlight this diversity. The simulation results presented in this report illustrate the diverse impacts of agricultural policies and their transfer efficiency across socioeconomic groups as well as across countries.

The DEVPEM framework was designed specifically to be replicable across developing countries. It is intended to be flexible enough to use for policy analysis in a diversity of settings, as well as to make efficient use of existing data from FAOSTAT and the RIGA household surveys. These are critical considerations if one wishes to use the model to evaluate policies in other countries at relatively low cost.

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Annex 1.

Summary Tables of DEVPEM Parameters, Variables, and Equation Blocks

Table A1.1. Sets, parameters, and variables in DEVPEM

Sets and subsets	Description	Subscript
I	Goods and factors	*gf*
G(I)	Goods	*g*
F (I)	Factors	*f*
TF(*F*)	Tradable factors	*tf*
FF(*F*)	Fixed factors	*ff*
A	Activities and nodes of activities in the CET (household-specific)	*a, or* η for nodes
A1(A)	CET branches at the top node (*node1*)	
A2(A)	CET branches at the medium node(*node2*)	
A3(A)	CET branches at the bottom node (*node3*)	
H	Households	*h*
MAH(A,H)	Mapping of activities to households that do them	
MAG(A,G)	Mapping of activities to goods they produce	
Parameters (lowercase letters)	**Description**	**Source**
p^m_{gf}	Market prices	assumption
$t^s_{h,gf}$, $t^b_{h,gf}$	Multiplicative transaction costs (seller, buyer)	assumption
$endow_{h,gf}$	Initial endowments (fixed in the case of land)	computation
$inpsupel_{gf}$	Supply elasticity for tradable inputs (imperfectly elastic)	assumption
$cmin_h$	Incompressible consumption level of good *g* for household *h*	assumption
$exinc_h$	Exogenous income for household h	computation
$\alpha_{h,g}$	Exponent in consumption function	computation
$\beta_{a,f}$	Exponent in production function of activity *a*	computation
γ_a	CET share parameters of activity *a*	computation
ρ^η_h	CET exponents (household-specific, one for each node η)	computation
Variables (uppercase letters)	**Description**	
QP_a	Quantities produced by household-specific activity *a*	
$QB_{h,gf}$, $QS_{h,gf}$	Quantities of *g* bought or sold by *h*	
$QC_{h,g}$	Quantities of *g* consumed by household *h*	
$FD_{a,f}$	Input of factor *f* into activity *a*.	
QM_{gf} , QE_{gf}	Quantities imported or exported of good or factor *gf*	
$INPS_{gf}$	Supply of tradable inputs (imperfectly elastic)	
$P_{h,gf}$ (or $P_{a,gf}$)	Prices faced by a household (or household-specific activity)	
$INPP_{gf}$	Prices of tradable inputs	
$R_{a,ff}$	Land or capital rent for household-specific activity or CET node	
W	Rural wage	
Y_h	Shadow income	
TLS_h	Total land supply by household	

Table A1.2. Equation blocks in DEVPEM

Equations	Description
Price bounds and complementary slackness	
$P_{h,gf} \leq p^m_{gf} \cdot t^b_{h,gf}$; $P_{h,gf} \geq p^m_{gf} \cdot t^s_{h,gf}$ $QB_{h,gf}\left(P_{h,gf} - p^m_{gf} \cdot t^b_{h,gf}\right) = 0$; $QS_{h,gf}\left(P_{h,gf} - p^m_{gf} \cdot t^s_{h,gf}\right) = 0$	Price bands, $gf \notin FF$
$P_{h,labor} = W$	Market wage
Input supply block	
$P_{h,input} = INPP_{input}$	Equalised price of inputs across households
$\frac{INPS_{input}}{INPS_{input,0}} = \left(INPP_{input}\right)^{inpsupel_{input}}$	Imperfectly elastic supply of input
$\sum_{a \in A} FD_{a,input} = INPS_{input}$	Market clearing for tradable inputs
Consumption block	
$QC_{h,g} = \frac{\alpha_{h,g}}{P_{h,g}}\left(Y_h - \sum_{I} P_{h,g} c_{h,g}\right) + c_{h,g}$	Demand from household *h* for good *g*, $gf \notin FF$
$Y_h = W \cdot endow_{h,labor} + \sum_{f \in FF} \sum_{a \in MAH} FD_{a,f} \cdot R_{a,f}$	Shadow income of household *h*
$\sum_{gf \in N} QS_{h,gf} \cdot P_{h,gf} + exinc_h = \sum_{gf \in N} QB_{h,gf} \cdot P_{h,gf}$	Cash constraint of household *h*
Production block	
$QP_a = b_a \prod_{f \in F} \left(FD_{a,f}\right)^{\beta_{a,f}}$	Production function
$FD_{a,tf} \cdot P_{a,tf} = P_{(a,g) \in MAG} \cdot QP_a \cdot \beta_{a,tf}$	Demand for tradable factor *tf* in the production of good *g* using activity *a*
$FD_{a,ff} \cdot R_{a,ff} = P_{(a,g) \in MAG} \cdot QP_a \cdot \beta_{a,ff}$	Demand for non-tradable factor *ff* in the production of good *g* using activity *a*
$FD_{a,capital} = \overline{FD_{a,capital}}$	Fixed levels of capital
CET land allocation block	
$\overline{TLS}_h = \left(\sum_{a \in A_1} \gamma_a \cdot \left(FD_{a,land}\right)^{\rho^1_h}\right)^{1/\rho^1_h}$	CET land supply, top node (η=1)
$FD_{node2,land} = \left(\sum_{a \in A_2} \gamma_a \cdot \left(FD_{a,land}\right)^{\rho^2_h}\right)^{1/\rho^2_h}$	CET land supply, middle node (η=2)
$FD_{node3,land} = \left(\sum_{a \in A_3} \gamma_a \cdot \left(FD_{a,land}\right)^{\rho^3_h}\right)^{1/\rho^3_h}$	CET land supply, lower node (η=3)
$\frac{R_{a,land}}{R_{a',land}} = \frac{\gamma_{h,a}}{\gamma_{h,a'}} \cdot \left(\frac{FD_{a,land}}{FD_{a',land}}\right)^{\rho^\eta_h - 1}$	CET optimality condition at every node η
$R_{\eta,land} = \left[\sum_{a \in A_\eta} \left(\gamma_a\right)^{\frac{1}{1-\rho^\eta_h}} \cdot \left(R_a\right)^{\frac{\rho^\eta_h}{\rho^\eta_h - 1}}\right]^{\frac{1-\rho^\eta_h}{\rho^\eta_h}}$	Implicit rent at a CET node η
Market clearing constraints	
$\sum_{a \in MAH} QP_a + QB_{h,gf} + endow_{h,gf} = QS_{h,gf} + QC_{h,gf} + \sum_{a \in MAH} FD_{a,h}$	Quantity balance at the household level
$\sum_{h \in H} QS_{h,gf} + QM_{gf} = \sum_{h \in H} QB_{h,gf} + QE_{gf}$	Quantity balance for the rural sector
$QS_{h,gf} \cdot QB_{h,gf} = 0$	Households buy or sell, not both

Annex 2.

Household Characteristics for the Social Accounting Matrices

Table A2.1. Bangladesh: Household characteristics

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Consumption shares							
rice	12%	10%	7%	30%	17%	17%	7%
other food staples	25%	9%	4%	25%	16%	13%	7%
other annual food crops	15%	10%	6%	27%	18%	16%	7%
cash crops	0%	0%	0%	0%	0%	0%	0%
fruits	22%	8%	9%	24%	16%	15%	8%
livestock	20%	8%	11%	24%	14%	15%	8%
Production shares							
rice		0%	6%	20%	14%	37%	23%
other staples		0%	4%	16%	17%	33%	30%
other annual food crops		0%	4%	17%	12%	40%	27%
cash crops		0%	5%	17%	11%	38%	29%
fruits		0%	5%	25%	9%	40%	21%
livestock		0%	9%	27%	11%	33%	20%
Household budget shares							
rice		10%	5%	7%	22%	8%	6%
other staples		3%	1%	2%	7%	2%	2%
other annual food crops		4%	2%	2%	9%	3%	2%
cash crops		0%	0%	0%	0%	0%	0%
fruits		1%	0%	0%	2%	1%	0%
livestock		6%	6%	4%	13%	5%	4%
market goods		77%	87%	84%	48%	82%	86%
Factor shares							
Rice							
own labour			52%	49%	42%	44%	27%
own capital			4%	4%	4%	4%	4%
own land			2%	3%	15%	12%	27%
hired labour			6%	7%	10%	9%	19%
intermediate inputs			36%	37%	29%	31%	23%

Table A2.1. Bangladesh: Household characteristics (*cont.*)

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Other staples							
own labour			42%	56%	37%	40%	13%
own capital			4%	4%	4%	4%	4%
own land			4%	6%	34%	26%	70%
hired labour			6%	3%	1%	5%	2%
intermediate inputs			44%	31%	24%	25%	11%
Other annual food crops							
own labour			65%	68%	53%	49%	20%
own capital			4%	4%	4%	4%	4%
own land			11%	14%	14%	30%	65%
hired labour			5%	2%	7%	3%	1%
intermediate inputs			15%	12%	22%	14%	10%
Cash crops							
own labour			67%	55%	48%	40%	15%
own capital			4%	4%	4%	4%	4%
own land			8%	11%	28%	16%	54%
hired labour			2%	5%	3%	3%	4%
intermediate inputs			19%	25%	17%	37%	23%
Fruits							
own labour			80%	79%	23%	10%	11%
own capital			4%	4%	4%	4%	4%
own land			14%	12%	46%	83%	81%
hired labour			1%	1%	1%	1%	1%
intermediate inputs			2%	4%	26%	2%	3%
Livestock							
own labour			19%	20%	13%	10%	6%
own capital			27%	33%	37%	29%	21%
own land			1%	0%	9%	6%	13%
hired labour			0%	0%	7%	2%	5%
intermediate inputs			53%	47%	35%	54%	55%
Land CET parameters							
Level 1 (σ1)			-0.13	-0.13	-0.16	-0.13	-0.13
Level 2 (σ2)			-0.41	-0.81	-0.46	-0.71	-0.61
Level 3 (σ3)			-0.55	-0.55	-0.55	-0.55	-0.55

Table A2.2. Ghana: Household characteristics

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Consumption share							
tubers	13%	4%	3%	23%	18%	26%	14%
other annual food	19%	5%	3%	22%	10%	27%	14%
plantains	18%	6%	2%	18%	12%	28%	16%
cocoa	0%	0%	0%	0%	0%	0%	0%
other tree crops	16%	3%	6%	17%	29%	20%	10%
livestock	22%	5%	2%	18%	13%	17%	22%
Production shares							
tubers		0%	2%	19%	12%	38%	29%
other annual food		0%	2%	12%	13%	42%	31%
plantains		0%	2%	12%	11%	39%	36%
cocoa		0%	2%	3%	20%	24%	51%
other tree crops		0%	2%	22%	10%	41%	25%
livestock		0%	3%	25%	16%	33%	23%
Household budget shares							
tubers		19%	30%	18%	46%	18%	15%
other annual food		16%	16%	11%	16%	11%	9%
plantains		11%	8%	5%	11%	7%	6%
cocoa		0%	0%	0%	0%	0%	0%
other tree crops		1%	3%	1%	3%	1%	0%
livestock		4%	3%	2%	4%	2%	3%
market goods		50%	40%	63%	20%	61%	66%
Factor shares							
Tubers							
own labour			91%	60%	63%	58%	42%
own capital			4%	4%	4%	4%	4%
own land			1%	7%	1%	5%	9%
hired labour			0%	13%	16%	17%	24%
intermediate inputs			4%	16%	16%	18%	21%
Other annual food crops							
own labour			58%	53%	75%	56%	45%
own capital			4%	4%	4%	4%	4%
own land			10%	10%	7%	14%	22%
hired labour			11%	15%	5%	10%	11%
intermediate inputs			17%	18%	9%	16%	18%
Plantains							
own labour			73%	63%	37%	43%	37%
own capital			4%	4%	4%	4%	4%
own land			1%	10%	8%	10%	21%
hired labour			9%	11%	18%	20%	16%
intermediate inputs			13%	12%	33%	23%	22%

Table A2.2. Ghana: Household characteristics (*cont.*)

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Cocoa							
own labour			92%	62%	37%	56%	49%
own capital			4%	4%	4%	4%	4%
own land			1%	15%	9%	1%	14%
hired labour			0%	2%	13%	18%	14%
intermediate inputs			3%	17%	37%	21%	19%
Other tree crops							
own labour			73%	63%	37%	43%	37%
own capital			4%	4%	4%	4%	4%
own land			1%	10%	8%	10%	21%
hired labour			9%	11%	18%	20%	16%
intermediate inputs			13%	12%	33%	23%	22%
Livestock							
own labour			73%	59%	79%	56%	29%
own capital			7%	13%	5%	6%	8%
own land			4%	14%	8%	30%	48%
hired labour			1%	2%	3%	3%	8%
intermediate inputs			15%	12%	4%	4%	7%
Land CET parameters							
Level 1 (σ1)			-0.10	-0.11	-0.11	-0.11	-0.10
Level 2 (σ2)			-1.82	-1.15	-1.09	-1.03	-1.25
Level 3 (σ3)			-0.55	-0.55	-0.55	-0.55	-0.55

Table A2.3. Guatemala: Household characteristics

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Consumption shares							
maize	19%	3%	12%	33%	10%	17%	6%
other annual food	25%	3%	17%	25%	17%	9%	4%
annual cash crops	27%	5%	7%	38%	5%	13%	5%
coffee	0%	0%	0%	0%	0%	0%	0%
fruits	26%	3%	5%	25%	27%	9%	4%
livestock	37%	5%	8%	30%	8%	9%	4%
Production shares							
maize		0%	12%	31%	10%	29%	18%
other annual food		0%	9%	33%	9%	32%	16%
annual cash crops		0%	2%	19%	14%	28%	37%
coffee		0%	3%	9%	19%	43%	26%
fruits		0%	2%	44%	10%	26%	19%
livestock		0%	10%	24%	10%	32%	25%
Household budget shares							
maize		3%	10%	4%	6%	3%	2%
other annual food		3%	12%	3%	9%	1%	1%
annual cash crops		0%	0%	0%	0%	0%	0%
coffee		0%	0%	0%	0%	0%	0%
fruits		1%	2%	1%	6%	1%	1%
livestock		14%	17%	10%	12%	5%	4%
market goods		79%	59%	83%	68%	90%	93%
Factor shares							
Maize							
own labour			54%	29%	32%	22%	23%
own capital			4%	4%	4%	4%	4%
own land			15%	26%	22%	30%	31%
hired labour			4%	8%	10%	15%	14%
intermediate inputs			23%	33%	32%	29%	28%
Other annual food crops							
own labour			53%	48%	62%	33%	32%
own capital			4%	4%	4%	4%	4%
own land			6%	8%	1%	17%	7%
hired labour			5%	8%	11%	10%	14%
intermediate inputs			32%	32%	22%	36%	43%

Table A2.3. Guatemala: Household characteristics (*cont.*)

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Annual cash crops							
own labour			46%	48%	52%	15%	21%
own capital			4%	4%	4%	4%	4%
own land			4%	4%	39%	33%	53%
hired labour			14%	14%	3%	17%	5%
intermediate inputs			34%	34%	6%	34%	20%
Coffee							
own labour			27%	27%	43%	32%	18%
own capital			4%	4%	4%	4%	4%
own land			49%	49%	21%	29%	28%
hired labour			2%	2%	12%	14%	18%
intermediate inputs			18%	18%	20%	21%	32%
Fruits							
own labour			32%	32%	30%	26%	2%
own capital			4%	4%	4%	4%	4%
own land			21%	21%	24%	29%	27%
hired labour			10%	10%	11%	12%	32%
intermediate inputs			33%	33%	31%	29%	35%
Livestock							
own labour			22%	11%	26%	42%	46%
own capital			49%	61%	26%	31%	21%
own land			1%	1%	7%	1%	1%
hired labour			1%	2%	3%	3%	19%
intermediate inputs			26%	25%	39%	24%	18%
Land CET parameters							
Level 1 (σ1)			-0.19	-0.14	-0.15	-0.16	-0.13
Level 2 (σ2)			-2.85	-5.00	-1.50	-9.36	-11.77
Level 3 (σ3)			-0.55	-0.55	-0.55	-0.55	-0.55

Table A2.4. Malawi: Household characteristics

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Consumption shares							
maize	5%	2%	4%	23%	10%	40%	16%
rice	12%	2%	5%	17%	28%	26%	10%
Other annual food	3%	1%	8%	14%	38%	25%	11%
tobacco	0%	0%	0%	0%	0%	0%	0%
tree crops	4%	1%	11%	18%	28%	26%	12%
livestock	11%	3%	3%	21%	14%	32%	16%
Production shares							
maize		0%	3%	7%	8%	39%	43%
rice		0%	5%	9%	30%	35%	21%
Other annual food		0%	3%	8%	15%	40%	34%
tobacco		0%	0%	1%	22%	57%	20%
tree crops		0%	6%	17%	15%	39%	23%
livestock		0%	4%	13%	16%	38%	29%
Household budget shares							
maize		18%	10%	17%	7%	9%	5%
rice		4%	3%	3%	4%	1%	1%
Other annual food		10%	37%	19%	49%	11%	7%
tobacco		0%	0%	0%	0%	0%	0%
tree crops		3%	15%	7%	10%	3%	2%
livestock		14%	6%	9%	6%	4%	3%
market goods		50%	29%	45%	24%	71%	82%
Factor shares							
Maize							
own labour			67%	49%	52%	39%	24%
own capital			4%	4%	4%	4%	4%
own land			21%	27%	30%	27%	34%
hired labour			0%	3%	3%	9%	13%
intermediate inputs			8%	17%	11%	22%	25%
Rice							
own labour			77%	74%	75%	75%	35%
own capital			4%	4%	4%	4%	4%
own land			1%	17%	5%	9%	25%
hired labour			10%	2%	6%	4%	9%
intermediate inputs			8%	3%	10%	8%	27%
Other annual food crops							
own labour			64%	55%	67%	63%	59%
own capital			4%	4%	4%	4%	4%
own land			14%	22%	10%	9%	9%
hired labour			4%	3%	4%	4%	8%
intermediate inputs			14%	16%	15%	20%	20%

Table A2.4. Malawi: Household characteristics (*cont.*)

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Tobacco							
own labour			46%	42%	42%	38%	22%
own capital			4%	4%	4%	4%	4%
own land			22%	23%	19%	25%	26%
hired labour			1%	0%	2%	2%	7%
intermediate inputs			27%	31%	33%	31%	41%
Tree crops							
own labour			26%	8%	3%	2%	1%
own capital			4%	4%	4%	4%	4%
own land			56%	73%	68%	75%	74%
hired labour			1%	1%	1%	3%	1%
intermediate inputs			13%	14%	24%	16%	20%
Livestock							
own labour			54%	42%	50%	39%	33%
own capital			10%	8%	12%	14%	21%
own land			23%	33%	25%	26%	27%
hired labour			1%	3%	2%	4%	4%
intermediate inputs			11%	14%	11%	16%	14%
Land CET parameters							
Level 1 (σ1)			-0.10	-0.10	-0.10	-0.10	-0.10
Level 2 (σ2)			-0.94	-0.78	-0.49	-0.50	-0.81
Level 3 (σ3)			-0.55	-0.55	-0.55	-0.55	-0.55

Table A2.5. Nicaragua: Household characteristics

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Consumption shares							
maize	39%	1%	9%	17%	25%	6%	2%
beans	36%	2%	9%	21%	20%	9%	3%
other annual food	53%	2%	6%	16%	16%	6%	2%
tree crops	53%	2%	8%	14%	15%	6%	2%
cash crops	0%	0%	0%	0%	0%	0%	0%
livestock	71%	2%	2%	16%	2%	5%	2%
Production shares							
maize		0%	6%	31%	16%	29%	17%
beans		0%	7%	24%	16%	30%	22%
other annual food		0%	6%	25%	16%	38%	15%
tree crops		0%	6%	31%	12%	38%	11%
cash crops		0%	2%	9%	18%	47%	24%
livestock		0%	8%	27%	17%	24%	24%
Household budget shares							
maize		1%	4%	1%	7%	1%	1%
beans		3%	6%	2%	11%	2%	2%
other annual food		4%	8%	3%	14%	2%	2%
tree crops		1%	2%	1%	4%	1%	1%
cash crops		0%	0%	0%	0%	0%	0%
livestock		10%	5%	6%	4%	4%	5%
market goods		80%	74%	86%	60%	90%	90%
Factor shares							
Maize							
own labour			74%	71%	65%	58%	37%
own capital			4%	4%	4%	4%	4%
own land			4%	4%	13%	13%	33%
hired labour			2%	3%	4%	8%	11%
intermediate inputs			16%	18%	14%	17%	15%
Beans							
own labour			64%	53%	51%	34%	34%
own capital			4%	4%	4%	4%	4%
own land			28%	27%	30%	37%	37%
hired labour			0%	0%	0%	5%	5%
intermediate inputs			4%	16%	15%	20%	20%
Other annual food crops							
own labour			43%	56%	41%	45%	14%
own capital			4%	4%	4%	4%	4%
own land			43%	10%	35%	28%	45%
hired labour			0%	4%	0%	9%	25%
intermediate inputs			10%	26%	20%	16%	12%

Table A2.5. Nicaragua: Household characteristics (*cont.*)

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Tree crops							
own labour			62%	60%	39%	20%	21%
own capital			4%	4%	4%	4%	4%
own land			5%	11%	11%	16%	16%
hired labour			0%	9%	14%	25%	25%
intermediate inputs			29%	16%	32%	35%	34%
Cash crops							
own labour			70%	41%	67%	50%	11%
own capital			4%	4%	4%	4%	4%
own land			3%	21%	18%	15%	27%
hired labour			4%	19%	0%	13%	37%
intermediate inputs			19%	15%	11%	18%	21%
Livestock							
own labour			46%	52%	39%	31%	12%
own capital			21%	16%	16%	19%	19%
own land			1%	1%	1%	1%	1%
hired labour			1%	2%	17%	7%	27%
intermediate inputs			30%	29%	27%	41%	42%
Land CET parameters							
Level 1 (σ1)			-0.10	-0.12	-0.13	-0.13	-0.14
Level 2 (σ2)			-1.84	-1.35	-2.73	-4.05	-3.15
Level 3 (σ3)			-0.55	-0.55	-0.55	-0.55	-0.55

Table A2.6. Viet Nam: Household characteristics

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Consumption shares							
rice	8%	5%	3%	19%	24%	30%	10%
other food crops	14%	5%	4%	22%	10%	32%	12%
coffee	35%	5%	3%	19%	10%	19%	9%
other cash crops	0%	0%	0%	0%	0%	0%	0%
fruits	22%	5%	3%	20%	18%	22%	10%
livestock	15%	5%	3%	21%	16%	29%	11%
Production shares							
rice		0%	2%	10%	14%	51%	23%
other food crops		0%	2%	9%	18%	46%	25%
coffee		0%	0%	2%	9%	35%	54%
other cash crops		0%	1%	9%	13%	40%	37%
fruits		0%	3%	11%	16%	53%	17%
livestock		0%	3%	22%	15%	45%	15%
Household budget shares							
rice		13%	15%	9%	26%	9%	8%
other food crops		15%	22%	14%	13%	12%	12%
coffee		0%	0%	0%	0%	0%	0%
other cash crops		0%	0%	0%	0%	0%	0%
fruits		9%	11%	7%	14%	5%	5%
livestock		16%	21%	15%	25%	12%	13%
market goods		46%	30%	54%	21%	62%	62%
Factor shares							
Rice							
own labour			45%	44%	31%	30%	17%
own capital			4%	4%	4%	4%	4%
own land			10%	9%	16%	16%	29%
hired labour			3%	4%	4%	6%	9%
intermediate inputs			38%	39%	45%	44%	41%
Other annual food crops							
own labour			48%	49%	37%	36%	23%
own capital			4%	4%	4%	4%	4%
own land			6%	4%	12%	10%	19%
hired labour			3%	3%	5%	14%	11%
intermediate inputs			39%	40%	42%	36%	43%
Coffee							
own labour			42%	39%	22%	21%	14%
own capital			4%	4%	4%	4%	4%
own land			16%	16%	28%	21%	27%
hired labour			2%	1%	3%	14%	19%
intermediate inputs			36%	40%	43%	40%	36%

Table A2.6. Viet Nam: Household characteristics (*cont.*)

	0. Urban households	1. Rural non-farm	2. Small remote	3. Small non-remote	4. Medium remote	5. Medium non-remote	6. Large farms
Other cash crops							
own labour			80%	67%	36%	37%	27%
own capital			4%	4%	4%	4%	4%
own land			3%	10%	20%	26%	33%
hired labour			1%	2%	5%	4%	5%
intermediate inputs			12%	17%	35%	29%	31%
Fruits							
own labour			50%	52%	37%	31%	12%
own capital			4%	4%	4%	4%	4%
own land			22%	20%	30%	29%	27%
hired labour			2%	1%	3%	4%	12%
intermediate inputs			22%	23%	26%	32%	45%
Livestock							
own labour			29%	29%	33%	23%	20%
own capital			6%	7%	5%	6%	3%
own land			2%	1%	16%	14%	33%
hired labour			1%	1%	2%	4%	4%
intermediate inputs			62%	62%	43%	53%	40%
Land CET parameters							
Level 1 ($\sigma 1$)			-0.14	-0.14	-0.12	-0.13	-0.13
Level 2 ($\sigma 2$)			-0.55	-0.36	-0.30	-0.26	-0.29
Level 3 ($\sigma 3$)			-0.55	-0.55	-0.55	-0.55	-0.55