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Modeling the Welfare Impacts of Agricultural Policies in Developing Countries

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Abstract

This paper presents a new model which incorporates features of developing country agriculture that may be critical in shaping the welfare outcomes of alternative agricultural policies. The model features heterogeneous households linked through markets in a rural economy-wide structure, with endogenous market participation for farmers facing transactions costs. The model is used for policy simulations, including market price support, production subsidies, input subsidies, transaction cost removal, and unconditional cash transfers. Applications for six countries highlight the diversity of potential impacts of such policies. The simulation results suggest that there are circumstances under which some market interventions, such as input subsidies, may be only slightly less efficient at transferring incomes than direct payments.

Key words: agricultural household model, agricultural policy, simulation, transaction costs

JEL classification: O12, O13, Q12, Q18.

1. Introduction

A range of simulation models has been developed to examine the effects agricultural policies on incomes and welfare in both developed and developing countries. These models include partial equilibrium sector models, which link output and factor markets, and can be used to calculate impacts of policy changes and exogenous shocks on factor returns to farmers (Floyd, 1965; Gardner, 1987; Shaik et al., 2005; OECD, 2005). This class of models captures the principal characteristics of high-income-country agriculture, in which markets function smoothly and farms are operated effectively as profit-maximizing businesses.

Models designed to take account of policy impacts in developing countries need to account, at a minimum, for the fact that many farm households consume a significant share of what they produce, with many farm households being in fact net buyers of food (Singh et al., 1986). Household-level micro simulations have been used to calculate the effects of food price changes on net real incomes, accounting for impacts on both farm revenues and consumption expenditures (Zezza et al., 2008; Filipinski and Covarrubias, 2012). However, these exercises do not account for behavioural responses at the household level or for market level effects. In some cases, micro simulations have been appended to or nested within CGE models, in order to capture economy-wide interactions, for example through labour and other factor markets (Cockburn, 2001; Vos and De Jong, 2003; Annabi et al., 2005; de Souza Ferreira Filho and Horridge, 2005; Cororaton and Cockburn, 2007). Household disaggregation in those models is often obtained at the expense of commodity and activity details.

Models of the farm household have been used to depict the household's production, consumption and labour allocation decisions. When markets are missing or failing, those decisions are made jointly, which has important ramifications in terms of household response to market incentives and notably to policies (Singh, et al., 1986; de Janvry and Sadoulet, 2006). For instance, households isolated from markets by prohibitive transaction costs may see no benefits from market price supports, while factor-constrained households may not be as responsive to production incentives as households which can purchase or rent production factors.

Village economy models nest such farm household models within a model of the local (village) economy (Taylor and Adelman, 1996). Farm household models and extended village economy models reveal complex linkages between functioning and failing markets, in which the impacts of policy shocks may be transmitted in unexpected ways, and produce unexpected or seemingly perverse outcomes. For instance, Dyer, et al. (2006) show how a decrease in the price of maize may induce subsistence farmers to increase their maize production through the indirect effect on rural wages. Löfgren and Robinson (1999) use a stylised CGE model in which household market participation decisions are endogenous to demonstrate how production responses to price policies may be discontinuous when farmers face transaction costs. A comprehensive model of the agricultural sector in less-developed countries must consider the behavior of structurally diverse agents, including commercial farms, semi-subsistence and subsistence farms, and landless rural households, as well as the market linkages that connect them (Brooks et al., 2012).

This paper proposes a new model, the Development Policy Evaluation Model (DEVPEM), which captures the most salient attributes of these different modelling approaches in terms of their ability to shape welfare outcomes in developing countries. Specifically, we specify a rural general equilibrium model that nests farm household models and links them through commodity and factor markets. We consider a specific form of a missing market, in the form of transaction costs which disconnect “remote” farmers from output markets.

Models are developed for six developing countries: two in Africa (Ghana and Malawi); two in Asia (Bangladesh and Vietnam) and two in Latin America (Guatemala and Nicaragua). The models are constructed using household-level data from the FAO’s Rural Income Generating Activities (RIGA) database and market aggregates from the FAOSTAT database. The models are relatively stylised, and are used to demonstrate the potential for important differences in the distribution of welfare impacts across developing countries. A heuristic comparison with the OECD’s Policy Evaluation Model (PEM) also suggests some systemic differences between welfare impacts in developed and developing countries.

The structure of the paper is as follows: Section 2 describes the core features of the model, Section 3 discusses the main attributes of the six developing country applications; Section 4 provides the simulation results and Section 5 provides conclusions in terms of which policy options are likely to be more or less effective in poorer countries.

2. The Development Policy Evaluation Model (DEVPEM)

The Development Policy Evaluation Model (DEVPEM) is a rural economy model constructed by linking multiple farm household models in a general equilibrium framework, as in Taylor, et al. (2005).¹

2.1. Farm households

The basic building block of DEVPEM is the agricultural household model, in which production, consumption and labor allocation decisions may be interdependent (Singh et al., 1986). The household maximizes its utility through consumption of goods that are either home-produced or purchased, subject to constraints on cash income, factor endowments, and production technology. The total value of goods consumed is equal to the sum of all profits and the total market value of all endowments, the full income of the farm household.

On its consumption side, household h is assumed to solve a standard utility maximization problem. It faces a set G of goods g , of which it chooses quantities consumed ($QC_{h,g}$) to maximize 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:

¹ See the Appendix for a summary of notation and model equations. Details and features of the model excluded here for brevity can be studied in the report by Brooks et al. (2011b).

$$\max_{QC} U(QC_{h,g}) \text{ subject to } \sum_g QC_{h,g} \cdot P_{h,g} \leq Y_h \quad (1)$$

The same household may also be engaged in agricultural production. On its producer side, it seeks to maximize profit Π_a from each agricultural activity a . Drawing from a set F of factors of production and inputs f , the household uses factor quantities $FD_{a,f}$ producing 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 “factor” and index gf “good or factor”). Formally, this problem can be formulated as:

$$\begin{aligned} \max \Pi_a &= QP_a \cdot P_{a,g} - \sum_{f \in F} FD_{a,f} \cdot P_{a,f} + FD_{a,f} \cdot R_{a,f} \\ \text{subject to:} \quad & QP_a = QP_a(FD_{a,f}) \end{aligned} \quad (2)$$

Income is the link between the producer and consumer side of the household. The level of income results partly from the solution to the producer problem, and it imposes the constraint on the utility maximization problem. The full income of the household is equal to the total value of a household’s endowments of factors:

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

Endowments $Endow_{h,tf}$ of each tradable factor tf (such as labor), 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. For all activities a performed by household h (mapped in the set MAH), 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.

We impose functional forms on the utility and production functions to derive analytical solutions to the dual optimization 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 :

$$U_h = \prod_{g \in G} (QC_g - c_{h,g})^{\alpha_{h,g}} \quad (4)$$

Given these household preferences, it follows that the optimal consumption decisions ($QC_{h,g}$) are:

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

Production follows a Cobb-Douglas function with a shift parameter b_a and exponents $\beta_{a,f}$, expressed as:

$$QP_a = b_a \prod_{f \in F} (FD_{a,f})^{\beta_{a,f}} \quad (6)$$

The profit-maximizing factor demands ($FD_{a,f}$) are given by:

$$\begin{cases} FD_{a,tf} = \frac{P_{(a,g) \in MAG} \cdot QP_a \cdot \beta_{a,tf}}{P_{a,tf}} \text{ for tradable factors } (tf) \\ FD_{a,ff} = \frac{P_{(a,g) \in MAG} \cdot QP_a \cdot \beta_{a,ff}}{R_{a,ff}} \text{ for fixed factors } (ff) \end{cases} \quad (7)$$

where the set MAG maps each activity to the good it produces. For each good the difference between profit-maximizing production and utility-maximizing consumption is equal to net sales. The model can feature any number commodities and production factors. Our applications feature seven commodities (six agricultural commodities and a composite good, representing all consumption goods produced outside the rural economy), and five factors of production (family labor, hired labor, land, physical capital, and purchased inputs). The assumptions about the markets in which these goods and factors are traded are outlined below.

2.2. Market assumptions

DEVPEM is 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. Any aggregate agricultural production surplus is exported out of the rural economy to the “rest of the world” (including the urban economy) 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:

$$\sum_{h \in H} QS_{h,g} + QM_g = \sum_{h \in H} QB_{h,g} + QE_g \quad (8)$$

The market for intermediate agricultural inputs (*e.g.* seeds and fertilizer), on the other hand, follows an imperfectly elastic structure. Inputs suppliers are assumed to be outside 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 modeled as an increasing function of the price, with a constant price elasticity of supply:

$$\frac{INPS}{INPS_0} = \left(\frac{INPP}{INPP_0} \right)^\varepsilon \quad (9)$$

where $INPS$ denotes input supply, $INPP$ input price, ε price elasticity of supply, and subscript 0 the initial levels.

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

2.3. Fixed factor allocation

DEVPEM includes two fixed factors of production: land and capital. The treatment of capital is simple, with this factor 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 is only appropriate in the very short run, and 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:

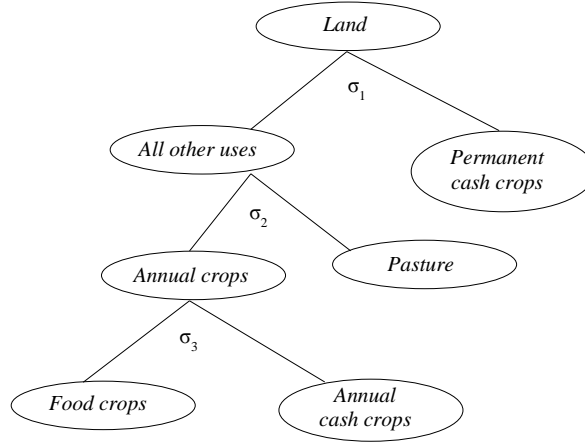
$$Endow_{land} = \sum_{g \in G} FD_{g,land} \quad (10)$$

where $Endow_{land}$ denotes the household's land endowment and $FD_{g,land}$ is the amount of land used in production of good g . 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:

$$Endow_{land} = S(FD_{g,land}) \quad (11)$$

DEVPEM has three levels of land transformability (or “nodes”, denoted by η), each with a different elasticity of transformation.² Figure 1 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 .

Figure 1. The three levels of land transformability in DEVPEM



DEVPEM imposes a constant elasticity of transformation (CET) structure on land allocation, following the OECD Policy Evaluation Model (OECD, 2005). 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 :

$$FD_{\eta,land} = \left(\sum_{a \in \eta} \gamma_a \cdot (FD_{a,land})^{\rho_h^\eta} \right)^{1/\rho_h^\eta} \quad (12)$$

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

$$\frac{R_{a,land}}{R_{a',land}} = \frac{\gamma_{h,a}}{\gamma_{h,a'}} \cdot \left(\frac{FD_{a,land}}{FD_{a',land}} \right)^{\rho_h^\eta - 1} \quad (13)$$

The optimal rent values at each node are given by:

² 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.

$$R_{\eta,land} = \left[\sum_{a \in A_{\eta}} (\gamma_a)^{\frac{1}{1-\rho_h^{\eta}}} \cdot (R_a)^{\frac{\rho_h^{\eta}}{\rho_h^{\eta}-1}} \right]^{\frac{1-\rho_h^{\eta}}{\rho_h^{\eta}}} \quad (14)$$

As a system, equations (12), (13), and (14) describe a single optimal solution to the land allocation problem.

2.4. Transaction costs in commodity markets

Equations (1) through (7) above describe the optimal behavior 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 be thought of as solving the consumer problem and the producer problem sequentially. First it maximizes its profit as a producer given prices of outputs and inputs, and then uses those profits to maximize utility, given prices of consumption goods. The maximization problems are said to be *separable*. This is not the case when households are isolated from markets by high transaction costs.

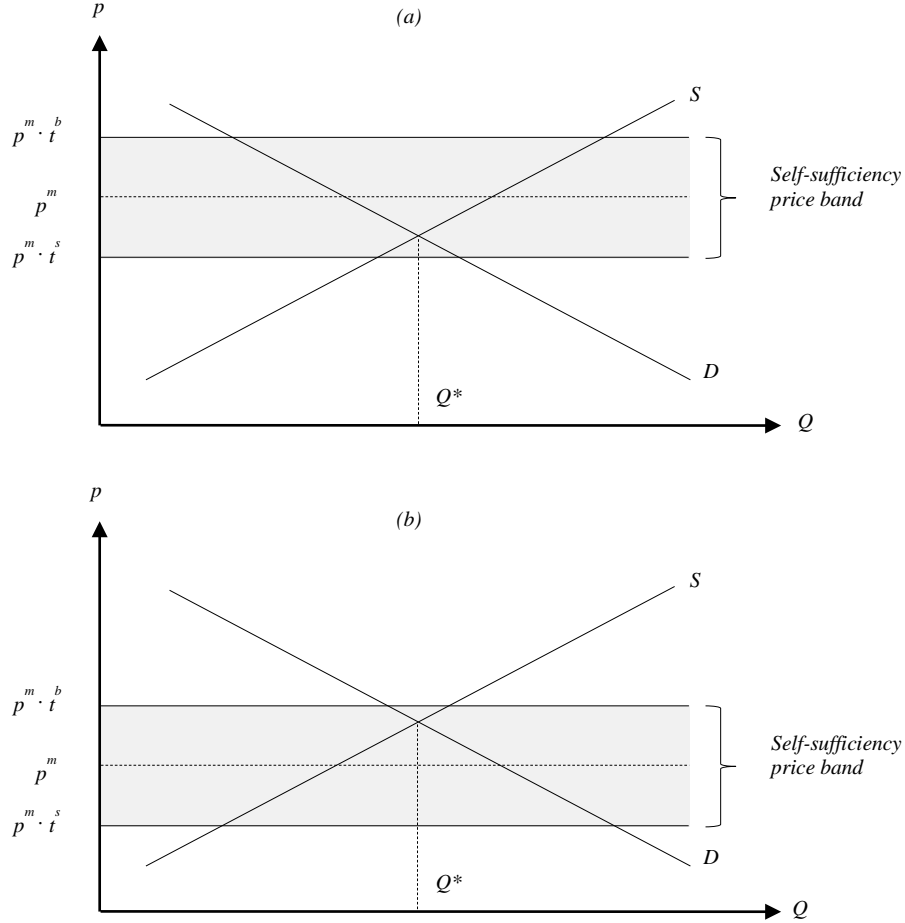
Transaction costs encompass any costs that an agent incurs in order to perform a market transaction. They are caused by, for example, long distances to markets, high transportation costs, poor infrastructure, non-competitive market structures, and incomplete information. A buyer facing transaction costs 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 and may prefer not to sell the commodities it produces, keeping 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 maximization become *non-separable*.

The treatment of market transaction costs is one of the key aspects in which DEVPEM differs from most general equilibrium models.³ In DEVPEM it is assumed that certain household groups face proportional transaction costs when participating in commodity markets. As buyers of consumption goods and inputs these household face an effective buying price ($p^m \cdot t^b$) that is higher than the market price ($t^b \geq 1$). As producers, they face an effective selling price ($p^m \cdot t^s$) 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 that, 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 $p^m \cdot t^s$ as the effective seller price, which is lower than its shadow price of the good. In this case the household does not participate in the market, 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 $p^m \cdot t^b$, which is higher than its shadow price of the good.

Additional constraints, such as poorly functioning factor markets and seasonal liquidity constraints, may also impede the responses of households to market price changes. These constraints are not captured directly by the DEVPEM. However, the assumptions of fixed capital and imperfect land reallocation capture, indirectly, the lack of well-functioning, formalized credit and land markets in the rural areas of many developing countries.

³ 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).

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



2.5. Household heterogeneity

A central hypothesis underlying DEVPEM is that agricultural policies have different welfare impacts on different rural household types. While the model is set up to handle any number of households, our applications capture household heterogeneity by partitioning all rural households into six separate categories, each with specific factor endowments, preferences, and production technology. 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 purpose of this classification is to capture heterogeneity in the constraints that households face and their resulting responses to external shocks. “Remote” households confront prohibitive transaction costs, as defined above, which may disconnect them from national commodity 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 which buy and sell on local, isolated markets. They are pure subsistence households in the model baseline, but their market participation status may change. The elements and defining characteristics of the DEVPEM model are summarized in Table 1.

Table 1. DEVPEM overview: household groups, production factors, and commodities.

<i>Households groups</i>	<i>Defining characteristic or assumption</i>
1. Non-farm households	Landless rural households, no farm income.
2. Small remote farm households	Face transaction costs for buying and selling farm goods.
3. Small non-remote farm households	Small land holdings, no transaction costs.
4. Medium-sized remote farm households	Face transaction costs for buying and selling farm goods.
5. Medium-sized non-remote farm households	Medium land holdings, no transaction costs.
6. Large farm households	Relatively large land holdings, no transaction costs.
<i>Factors of production</i>	<i>Defining characteristic or assumption</i>
1. Family labor	Used on the own farm or supplied on the rural labor market; wage rate determined endogenously.
2. Hired labor	Wage rate determined endogenously; not all farms hire labor.
3. Land	Missing market; imperfect transferability from one use to another.
4. Physical capital	Fixed in the short run (missing market).
5. Intermediate inputs (seeds, fertilizer, etc.)	Supplied by the urban economy at increasing marginal cost.
<i>Commodities</i>	<i>Defining characteristic or assumption</i>
1. Main cash crop	} Produced and consumed (partly) by rural households; price determined exogenously. (Classification varies to some degree by country.)
2. Main food staple	
3. Other food staples	
4. Other annual crops	
5. Other cash crops	
6. Livestock products	} Produced outside the rural economy; exogenous price.
7. Non-agricultural (“market”) goods	

3. Application of DEVPEM to six developing countries

We use DEVPEM to simulate the effects of agricultural policies in six countries: Ghana, Malawi, Guatemala, Nicaragua, Bangladesh, and Vietnam. The 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. This section describes briefly some key characteristics of the countries and how the six household groups are composed.

3.1. Data sources

The basic data platform for DEVPEM consists of disaggregated social accounting matrices, one for each household group, constructed with household survey data compiled by the United Nations Food and Agricultural Organization in its Rural Income Generation Activities (RIGA) database and with data from the FAOSTAT database.⁴ The virtue of the RIGA database is that variables have been standardized across countries, which makes it relatively straightforward to build and parameterize our models and helps ensure comparability across countries. The household survey data that are used in DEVPEM (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.

3.2. Country characteristics

Bangladesh, Ghana, and Malawi fall in the category of low-income countries, whereas Guatemala, Nicaragua, and Vietnam are lower-middle-income countries, according to the World Bank country classification. Table 2 provides a few economic indicators and other summary statistics for the six countries. Per-capita incomes range from USD 774 in Malawi to 4397 in Guatemala (2005 PPP US dollars). The six countries have structurally different economies. With over 80 percent of its population in rural areas, and with a third of the economy consisting of agricultural production, Malawi is a largely agriculture-based country. While Ghana has a lower share of its population in rural areas (50 percent), agriculture constitutes an equally large share of GDP as in Malawi. In Vietnam and Bangladesh, about three-quarters of the population live in rural areas, but agriculture plays a smaller role in both countries, constituting about 20 percent of GDP. Despite their large rural population shares, the economies of both Vietnam and Bangladesh are dominated by manufacturing and services. The agricultural sector accounts for less than 20 percent of GDP in Nicaragua and 12 percent in Guatemala.

The African and Asian countries have agricultural labor productivity ranging from USD 136 (per year and employee, constant 2000 dollars) to USD 418. Labor productivity in Guatemala and Nicaragua is an order of magnitude higher, at about 2 800 and 2 400 dollars, respectively. This difference reflects not only different levels of agricultural development but also different output compositions within the agricultural sector. Production in Ghana and Malawi is dominated by food crops, most of which are consumed locally, even though both countries have significant cash crop production (cocoa for Ghana; tobacco for Malawi). Rice production dominates in Bangladesh and Vietnam, while less labor-intensive production based on livestock and perennial crops are important in Guatemala and Nicaragua.

Table 2. Population, living standards, and agriculture in DEVPEM countries

	<i>African countries</i>		<i>Latin American countries</i>		<i>Asian countries</i>	
	Ghana	Malawi	Guatemala	Nicaragua	Bangladesh	Vietnam
Population and living standards						
Population, million	23.4	14.8	13.7	5.7	160.0	86.2
Rural population, % of total population	50.0	81.2	51.4	43.3	72.9	72.2
GDP per capita (PPP) ^a	1,351	744	4,397	2,473	1,233	2,574
GDP per capita, world ranking ^b	132	151	93	112	136	111
Poverty, USD 2 a day, % ^c	53.6	90.5	24.3	31.9	81.3	48.4
Poverty, USD 1.25 a day ^c	30.0	73.9	11.7	15.8	49.6	21.5
Agriculture						
Agr value added per worker ^d	401	136	2 815	2 408	418	352
Agriculture, % of GDP	33	34	12	19	19	22
Main food crops	yams, cassava, plantains	potatoes, maize, cassava	potatoes, maize, beans	maize, rice, beans	rice, potatoes, maize	rice, cassava, maize
Main non-food crops/commodities	cocoa beans	tobacco	sugar cane	sugar cane	chilies, jute	coffee, cashew

Note: Information is for year 2008 except for the poverty rates, which are based on the latest information available, 2001-2006.

^a Constant 2005 PPP US\$. ^b Of 160 countries in total. ^c Headcount ratio, PPP dollars, % of total population. ^d Constant 2000 PPP US\$. *Source:* World Development Indicators.

3.3. 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 the model. The purpose of distinguishing between household groups is to capture heterogeneity in household-level constraints 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. As explained

above, we define the household groups based on access to land and remoteness to markets. 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 also has the advantage of providing a basis for cross-country comparison.

Access to land was defined not in terms of land ownership but in terms of cultivated land, because formal ownership and cultivation rights granted by traditional authorities are all likely to be relatively secure in the short run. Rented or sharecropped land is rare in all of our surveys, which minimizes the potential error induced by this 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 laborers.

To define remoteness, we computed an index at the community level using distances to basic services or administrative centers (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 percent 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), so this assumption is, in our opinion, a reasonable one. This treatment of transaction costs is essentially a hybrid of the way in which transaction costs are modeled 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 emphasize 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.

3.4. Household characteristics

Agriculture's share of rural household income ranges from 50 percent in Guatemala to 77 percent in Ghana and Malawi. As evident in Table 3, among agricultural income sources, crop growing is relatively important in Malawi, Ghana, and Vietnam; livestock in Nicaragua and Vietnam; and agricultural wage labor 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 might have differential 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. However, the effects of any given agricultural policy will also depend on the type of agricultural activity that households are primarily engaged in. For example, 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. Among the DEVPEM household groups, income sources vary substantially, with large farmers generally deriving a larger share of their income from farming than small and medium-size farmers. The agricultural product mix differs by household categories, both within and across countries. Farm households of all six types in Malawi and Ghana are dominated by crop production. Cash crops tend to be dominant in Guatemala, especially among large farmers, while livestock dominates across all household groups in Nicaragua. In Vietnam, small and medium-size farmers grow primarily food crops (rice), while larger farmers have a substantial share of production allocated to cash crops. Food crops (rice) dominate among all household groups in Bangladesh.

The effects of policies will also depend on the degree to which farmers participate in markets and whether they are net buyers or sellers of affected goods. If few farmers are net sellers of crops, then crop price support is unlikely to provide much collective benefit. By assumption, the two household groups defined

as *remote* are self-sufficient in food crops. This means that, as a group, these households are treated in the model as if they do not trade with the rest of the economy, even though they may trade with each other locally, at prices that are disconnected from 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 let the data reveal the trading status of household groups in each country. As a whole, 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.

Table 3. Household income shares among rural households (percent)

	Ghana	Malawi	Guatemala	Nicaragua	Bangladesh	Vietnam
Crops	57.3	56.1	27.6	20.6	29.4	41.5
Livestock	13.2	9.4	2.6	14.5	14.4	14.8
Agr. wage employment	1.4	11.4	19.9	21.5	18.3	5.9
<i>Agriculture, total</i>	<i>77.0</i>	<i>77.0</i>	<i>50.1</i>	<i>56.6</i>	<i>62.1</i>	<i>62.2</i>
Non-ag. wage employment	6.1	7.4	20.2	21.3	17.5	9.2
Non-ag. self-employment	8.5	8.7	12.4	11.2	9.3	21.2
Transfers	6.2	6.6	16.9	6.2	9.8	7.0
Other income sources	2.2	0.3	0.5	4.7	1.2	0.3
<i>Non-agricultural sources, total</i>	<i>23.0</i>	<i>23.0</i>	<i>49.9</i>	<i>43.4</i>	<i>37.9</i>	<i>37.8</i>

Source: Winters et al. (2009), Table 2.

3.5. Model parameterization

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.

Aggregate production and consumption values

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 labor) 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:

$$VP_{g,h} = p_g Q_g \cdot PS_{g,h} \quad \left(\sum_h PS_{g,h} = 1 \quad \forall g \in G, g \neq m \right) \quad (15)$$

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:

$$VC_{g,h} = p_g Q_g \cdot CS_{g,h} \quad \left(\sum_h CS_{g,h} = 1 \quad \forall g \in G, g \neq m \right) \quad (16)$$

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:

$$VC_{m,h} = Y_h - \sum_{g \neq m} VC_{g,h} \quad (17)$$

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 for lack of data, 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):

$$s_{g,h}^e = \frac{VC_{g,h}}{Y_h} \quad (18)$$

Production technology

Household farm production technology is also assumed to be characterized 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 labor, hired labor, physical capital, land, and intermediate inputs (such as seeds and fertilizer). Let $VI_{f,g,h}$ denote the value of input f in the production of good g by household group h . Then:

$$VI_{f,g,h} = VP_{g,h} \cdot s_{f,g,h}^p \quad \left(\sum_{f \in F} s_{f,g,h}^p = 1 \quad \forall g \in G, g \neq m, \forall h \in H \right) \quad (19)$$

where $s_{f,g,h}^p$ 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.⁵

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 Policy Evaluation 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:

$$\sigma_1 = \frac{\varepsilon_{cc}}{(1-sr_c)} \quad (20)$$

⁵ 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.

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:

$$\sigma_2 = \frac{\overline{\varepsilon_{ii}} + 2\overline{\varepsilon_{ij}} - \sigma_1(sr_3/sr_2 - sr_3)}{1 - sr_3/sr_2} \quad (21)$$

ε_{ii} denoting own-price elasticity of land supply for any item i in the second nest, ε_{ij} 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:

$$\sigma_3 = \overline{\varepsilon_{ii}} - \overline{\varepsilon_{ij}} \quad (22)$$

i and j referring to items in the third nest. For a detailed derivation of these expressions, see OECD (2005). The challenge finding country-specific land supply elasticity estimates is greater for DEVPEM than for PEM, as reliable data for low-income countries 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 assume that the own-price elasticity of land supply to permanent crops, ε_{cc} , is 0.1; 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 elasticity values, 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 that 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.

4. Agricultural Policy Simulations with DEVPEM

We use DEVPEM to analyze the effects of five different policies in each of the six countries. 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 that *lowers transaction costs* for remote households and facilitates access to markets. We are interested primarily in the ability of each policy to increase the welfare of rural households and how cost efficient each policy is in terms of raising the welfare of the targeted population for every dollar spent on the policy.

The market price support (MPS) and production subsidy (PS) experiments 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, which are formally equivalent to a deficiency payment equal to the difference between a target support price and the market price, are rarely implemented in developing countries, as they necessitate the use of scarce budgetary resources. However, they provide an instructive comparison with MPS policies because of this basic difference in effect. Input subsidy (IS) policies consist of interventions in markets where farmers are buyers and non-farm consumers do not participate, such as the markets for seeds and fertilizer. Common to 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.⁶

4.1. Welfare effects of agricultural policies

The welfare effect of a given policy on a household is the net effect of gains on the production side, potential losses on the consumption side, and additional effects in the form of wage income changes. When analyzing the welfare impacts of different policies on rural households, it is important to distinguish between nominal income (measured in currency units) and real income (measured in purchasing power). We focus here on the simulated effects on real household income and define the *final welfare change* (or just the *welfare change*) as the change in real income after behavioral adjustments of households. The final welfare change is measured as a compensating variation, i.e. 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.

Market price support

The MPS policy is implemented 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, 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 analyze the effects of market price support for three agricultural commodities: the main food crop, the main cash crop, and livestock products. The experiment consists of raising the domestic price 10 percent above the world market price of one commodity at a 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 behavioral adjustments among households.

Table 4 gives an overview of the results. Market price support for food crops has the inherent weakness of tending to hurt some of its intended beneficiaries. A common effect in all six countries is that rural non-farm households lose or are, at best, virtually unaffected by the MPS policy for food crops. Their gains on the wage income side do not compensate for losses on the consumption side. The food MPS policy has small welfare effects on all household groups in Guatemala, Nicaragua, and Vietnam, whereas benefits are concentrated to large farmers in Malawi and Bangladesh. Only in Ghana is MPS for food able to raise welfare among all five farm household groups.

Since no one in the rural economy consumes the main cash crop, market interventions raising its price do not hurt rural consumers like the MPS on staples. Although non-farm households could potentially gain via an increased wage rate, the price change is not big enough to generate such an effect. The wage effect may be further limited by a relatively capital intensive technology used in cash crop production. The policy also bids up the price of commercial inputs such as fertilizer, which generates the (very mild) negative welfare impacts on small farms in Malawi. With the exception of Ghana, where small farmers grow cocoa beans, the net welfare effects of cash crop MPS are negligible also for small farmers and gains tend to be concentrated to medium-sized and large farmers (especially in the two Central-American countries, Guatemala and Nicaragua).

MPS for livestock products has the same weakness as MPS for food crops in that it hurts rural net-buyers. The simulation results suggest that non-farm households lose from livestock MPS in all six countries. Small farm households are either unaffected or suffer a small welfare loss in all countries but Nicaragua, where they gain significantly. In the two African countries and in Vietnam effectively no one benefits from the policy. Gains are small in Bangladesh and Guatemala, the only case in which MPS for livestock

⁶ Brooks et al. (2011a) analyses the simulation results in greater detail.

significantly increases welfare being for Nicaragua. The relatively large welfare gains in Nicaragua are explained by a large share of livestock in the product mix of Nicaraguan farmers.

The general tendency in the simulation results is that non-farm households and small farmers are likely to lose from increased food prices. To the extent that the price support policies generate welfare gains, the gains tend to be concentrated among large farmers, who are able to benefit from their position as large net sellers.

Table 4. Simulation results of rural household welfare effects of various agricultural policies (percentage change)

	Ghana	Malawi	Guatemala	Nicaragua	Bangladesh	Vietnam
Market price support, food staple						
Non-Farm	-0.11	-1.71	-0.25	0.31	-0.81	-0.89
Small Remote	2.60	-0.08	-0.03	0.29	-0.04	0.30
Small Non-remote	1.29	-0.93	0.03	0.49	-0.06	0.30
Medium Remote	0.68	-0.13	-0.04	0.16	-0.44	-0.51
Medium Non-Remote	2.32	0.25	0.26	0.63	0.91	1.46
Large Farm	2.29	1.22	0.40	0.28	1.02	1.05
Market price support, cash crop						
Non-Farm	0.34	0.00	0.23	0.44	0.01	0.15
Small Remote	1.26	-0.08	0.62	0.68	0.06	0.13
Small Non-remote	0.11	-0.04	0.25	0.34	0.07	0.20
Medium Remote	1.15	0.59	2.70	2.04	0.16	1.04
Medium Non-Remote	0.47	0.44	1.78	2.20	0.26	1.14
Large Farm	0.78	0.12	1.77	2.18	0.27	5.09
Market price support, livestock						
Non-Farm	-0.34	-1.37	-1.13	-0.21	-0.56	-1.36
Small Remote	-0.03	-0.01	-0.02	2.31	-0.15	-0.67
Small Non-remote	0.04	-0.38	-0.32	0.92	0.07	-0.38
Medium Remote	0.04	-0.01	-0.01	3.93	-0.22	-0.53
Medium Non-Remote	0.15	0.05	0.76	1.89	0.53	0.13
Large Farm	0.02	0.23	1.49	3.67	0.61	0.16
Production subsidy, food staple						
Non-Farm	1.68	0.01	0.04	0.42	0.12	0.32
Small Remote	2.60	-0.08	-0.03	0.29	-0.04	0.30
Small Non-remote	3.04	0.67	0.38	0.59	0.60	1.21
Medium Remote	0.68	-0.13	-0.04	0.16	-0.44	-0.51
Medium Non-Remote	4.08	1.13	0.56	0.71	1.66	2.32
Large Farm	3.68	1.74	0.57	0.35	1.57	1.82
Input subsidy						
Non-Farm	0.28	0.14	0.03	0.13	0.03	0.41
Small Remote	0.77	0.56	0.56	0.26	0.16	1.61
Small Non-remote	0.46	0.53	0.10	0.22	0.19	0.85
Medium Remote	1.25	0.80	0.72	0.59	0.62	2.54
Medium Non-Remote	0.88	0.88	0.88	0.67	0.56	1.77
Large Farm	1.14	1.03	1.20	0.68	0.37	2.80
Public-good investment						
Non-Farm	0.2	0.0	0.1	0.4	0.0	0.1
Small Remote	1.2	0.1	1.3	3.5	0.1	1.2
Small Non-remote	0.1	0.0	0.0	0.1	0.0	0.1
Medium Remote	3.5	0.7	4.4	7.2	0.2	5.3
Medium Non-Remote	0.0	0.0	-0.1	-0.1	0.0	-0.2
Large Farm	-0.1	-0.1	-0.2	-1.1	0.0	-0.5

Note: The market price support simulations assume a 10% exogenous price increase in the targeted commodity. The production subsidy simulations assume that farmers are given a 10% subsidy for all output produced of the targeted commodity. The input subsidy simulation assumes that farmers are given vouchers, which gives them 10% discount on the targeted agricultural input. The public-good investment simulation assumes that transaction costs are eliminated for households located remotely from markets. *Source:* DEVPEM simulation results.

Production subsidy

In contrast with market price support, a production subsidy does not affect consumers directly 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.

As with the MPS experiments, we analyze 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-percent mark-up on the world market price. Table 4 shows the simulation results of a production subsidy for the main food crop in each country. Similar to the case of MPS, production subsidies tend to benefit medium-sized and large farmers more than small farmers. The relatively large benefits in Ghana reflect the high shares of income coming from food crops. Remote households would only benefit from the production subsidy if they entered the market as staple sellers, but they can be negatively affected through the price of their tradable inputs. Indeed, welfare impacts for remote households in Malawi, Guatemala and Bangladesh carry negative signs, but their magnitudes are negligible.

Input subsidies

An input subsidy enables farm households to buy intermediate inputs at a lower price than the market price. While there are various ways of implementing such a policy, we assume here that the policy is implemented as vouchers given to farmers, effectively giving them a 10-percent discount on the targeted input.

We analyze the effects of an input subsidy under two scenarios with regard to input distribution channels. The benchmark assumption (reported in the table) is that the supply of inputs is relatively elastic, with price elasticity equal to 2.⁷ The alternative scenario (not reported) is that the input market is perfectly connected with the rest of the world so that the price is fully exogenous. Under that assumption welfare effects across household groups and across countries are about twice as large. This follows directly from the fact that there are no leakages as long as the suppliers are unable to affect the price (that is, raise the price above the world market price).

The lower part of Table 4 reveals that the welfare effects are generally in the range of 0.5 and 1 percent change, except in the case of Vietnam, where they are between 1 and 2.5 percent. With few exceptions, and similar to the other market-intervening policies, large farmers tend to gain more than small. While the final welfare change due to an input subsidy is the result of several behavioral changes and general-equilibrium effects, the effect is also determined by the intensity with which intermediate inputs are used in production. If fertilizer is subsidized but certain groups of farmers use very little fertilizer, their direct cost savings will be small, and the price change may not generate any large substitution effects (i.e. using relatively more of the subsidized fertilizer and less of other factors of production).

Public good investment

The notion of public goods is used here in a broad sense to distinguish goods that benefit a large group of people (such as roads, irrigation systems, public health centers, and schools) from 'private' goods (such as consumer goods and agricultural production equipment) that only benefit their sole owner. Rural public-goods investments are an agricultural policy only in the loose sense that they benefit people of whom a majority are farmers. The simulation of the public-good investment is designed so that remote households are freed from transaction costs on buying and selling agricultural commodities. Even though,

⁷ Few studies have examined this price elasticity of supply explicitly. Ryan and Perrin (1974), in an analysis of the Peruvian potato production, assume a perfectly elastic supply of fertilizer, given that it is imported. Quizón and Binswanger (1986), on the other hand, in a study of Indian agriculture, assume a fertilizer supply elasticity of 4, based on trade openness.

theoretically, there may be positive spill-over effects to other household groups, such effects are not significant in the simulation results; in effect, only the two remote household groups are affected by the policy.

As shown in the lower part of Table 4, the welfare effects on remote households vary greatly from country to country. The effects are close to zero in Bangladesh and Malawi, while 5 to 7 percent for the medium-size households in Nicaragua and Vietnam. The absence of benefits in Bangladesh and Malawi suggests that remote households face constraints other than transaction costs. If, for example, these households have in general very small endowments of land and production equipment, they will be unable to respond by increasing their production to any large extent. While simplistic in its design, this simulation shows that lowering transaction costs could have substantial welfare effects. It also shows that the effects may be small in other cases, i.e., if remotely located farm households face additional constraints to expand their production (such as important factors or production or lack of knowledge about the most efficient farming techniques).

An unconditional cash transfer

The benchmark with which the above policy shocks are compared is a cash transfer that is not tied to crop production or to a specific use of inputs. Theoretically, a cash transfer is the best way of raising the welfare of specific household groups since it does not affect incentives and does not involve leakages to unintended recipients. Moreover, it can in principle be targeted to poorer households. The use of any other instrument is therefore likely to reflect either administrative challenges or the simultaneous pursuit of other policy objectives, as discussed in the introduction. The way we simulate the cash transfer in this study is essentially trivial, with each farm household group receiving a cash transfer equal to 1 percent of household income.

Theoretically, a cash transfer could generate multiplier effects in a way that final welfare among rural households increased more than 1 percent. However, effectively all household groups in all countries experience exactly a 1-percent change in final welfare due to the transfer. Multiplier effects may only be visible with transfers of a larger magnitude or when additional constraints on household production are modeled explicitly, such as risk or liquidity constraints.

4.2. Assessing the relative efficiency of policies

From a cost-benefit perspective, the most efficient policy instrument is the one best at achieving the target benefit at lowest cost. We measure policy efficiency as the ratio of the aggregate change in rural household welfare to total urban cost of the policy:

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

We assume that all explicit costs of the policy, in terms of taxpayer costs, are borne by the urban population. For policies affecting urban consumer prices (the MPS policies), urban households also face implicit costs in the form of consumer surplus losses.⁸ Hence, our policy efficiency measure gives the rural dollar welfare change for every dollar of cost imposed on urban consumers and taxpayers. The efficiency measure disregards the distribution of the rural welfare gains and only considers the aggregate change. In addition, it does not reflect influences not explicitly captured in the model, including a loosening of liquidity or risk constraints that could, in theory, produce efficiency rates greater than 100 percent.

The efficiency measures from the different policies are summarized in Table 5. The benchmark experiment of an unconditional cash transfer, as designed, has a cost efficiency of 100 percent. As we

⁸ These consumer losses are calculated outside the model assuming an urban own price elasticity of demand of 1 for food crop and livestock consumption. Given that demand is more likely to be relatively inelastic, the resulting cost efficiency ratios for food price support place a lower bound on the urban costs and an upper bound on cost efficiency.

discussed, we do not take into account any administrative costs or implementation failures but simply assume that every farm household is given a transfer equal to 1 percent of its income. The underlying model assumptions affect the ranking of policy instruments in terms of cost efficiency. The input subsidy is, on average, the most efficient policy after a cash transfer, under the assumption that the price of the targeted input (e.g., fertilizer) is exogenous. On average, of each urban dollar spent on the policy, 91 cents are transferred as welfare improvements among rural households. If, however, the price of the targeted input is not exogenous but rises due to changes in rural demand, the average level of efficiency falls to 54 cent per urban dollar spent on the policy. Among the policies that involve interventions in commodity markets, those without negative consumer side-effects have higher levels of efficiency. The efficiency of the produced subsidy exceeds 70 percent, while the efficiency of MPS to cash crops is on average 67 percent. The policies with the lowest levels of efficiency are those that hurt rural households on the consumption side, namely price supports for food crops and livestock products, with efficiency levels below 50 percent in many cases. The efficiency of these measures is also harmed by price increases on the input market.

Table 5. Aggregate cost efficiency of policies, in the order of average level of efficiency (percent)

	Malawi	Ghana	Guatemala	Nicaragua	Bangladesh	Vietnam	<i>Average</i>
Unconditional cash transfer	100	100	100	100	100	100	<i>100</i>
Input subsidy, exogenous price	90	90	81	100	91	92	<i>91</i>
PS, livestock products	89	93	87	65	63	50	<i>75</i>
PS, main food staple	78	76	76	75	67	63	<i>72</i>
MPS, main cash crop	54	47	83	84	63	72	<i>67</i>
Input subsidy, endogenous price	56	57	46	60	53	52	<i>54</i>
MPS, main food staple	47	62	46	71	30	44	<i>50</i>
MPS, livestock products	23	67	49	61	29	0	<i>38</i>

Note: MPS – market price support (10% of market price), PS – production subsidy (10% of market price), input subsidy (10% of market price).

While patterns differ across countries, the general conclusion is that input subsidies are the most cost efficient instrument after cash transfers, provided that input prices do not rise as a result of increases in demand. If prices rise, the efficiency of input subsidies might be no higher than interventions in agricultural output markets that do not to affect consumer prices. In general, production subsidies tend to be more cost effective than market price supports. This is because they affect neither rural nor urban consumer prices, so the rural net benefits are higher and the urban costs are lower.

5. Conclusions

DEVPEM was developed 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. The dual nature of agricultural households as producers and consumers implies that increases in commodity prices create both positive income and negative consumption effects in agricultural households. The model was designed specifically to be replicable across different 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.

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 a greater share of policy-induced increases in the returns to land (e.g., due to MPS or input subsidies) accrue to agricultural households in DEVPEM, rather than being capitalized as land rents paid by farmers to landowners as is the case in models such as the OECD Policy Evaluation Model.. 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 results of the policy simulations show that, for alternative policy instruments, there are significant differences in household-level impacts across countries. The observed effects also differ in some systemic ways with those found in analyses of OECD countries (OECD, 2001, 2005). This is due in part to the recognition that most farm households consume as well as produce food and in part due to differences in resource constraints and factor endowments. Some general findings stand out:

Market price support for food crops harms net buyers of food, often the poorest farm and non-farm (landless) households, although the proportion of net buyers varies significantly across countries. Support for cash crops does not have this drawback; however, cash crops are typically grown by farmers with relatively high incomes, so support seldom reaches the incomes of the poorest.

An untargeted cash transfer based on current income aggravates rural income inequality, but by less than untargeted agricultural policies, and in principle a cash transfer can be targeted to low income households. In policy terms, the question is therefore whether there are considerations outside the scope of the model which might militate against the use of direct transfers. One is administrative difficulties, for example due to the absence of a population registry, or because of concerns about corruption (although these concerns also apply to other instruments). Another is the possibility of dynamic gains from market interventions, in terms of enabling farmers to break out of poverty traps.

Untargeted input subsidies tend to benefit those farmers who are using inputs already – often larger farmers. The extent to which the benefits of either input or output price support are retained by farmers depends partly on the degree to which the price of inputs rises in response to the increase in input demand. Parallel investments that increase distribution capacity and help keep marginal distribution costs constant would reduce the leakage of benefits away from the farmer. Input subsidies can also in principle be targeted to improve their distributional outcomes.

Public investment in reducing transaction costs is the only instrument studied here that can be considered directly pro-poor, since it helps remote farm households who are typically poorer than those engaged with markets. However, we do not know the cost of generating these improvements. In general, the results show that direct payments are the most efficient way of boosting incomes in the short-term, while public investments, which should have broader long-term pay-offs, have short to medium term impacts that are pro-poor.

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Appendix 1. Summary tables of model parameters, variables and blocks of equations

Table A1. Sets, parameters, and variables in DEVPEM

<i>Sets and subsets</i>	<i>Description</i>	<i>Subscript</i>
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	
<i>Parameters</i> (lowercase letters)	<i>Description</i>	<i>Source</i>
p_{gf}^m	Market prices	assumption
$t_{h,gf}^s, t_{h,gf}^b$	Multiplicative transaction costs (seller, buyer)	assumption
$endow_{h,gf}$	Initial endowments (fixed in the case of land)	computation
ε_{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_h^η	CET exponents (household-specific, one for each node η)	computation
<i>Variables</i> (uppercase letters)	<i>Description</i>	
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 A2. Equation blocks in DEVPEM

Equations	Description
Price bounds and complementary slackness	
$P_{h,gf} \leq p_{gf}^m \cdot t_{h,gf}^b$; $P_{h,gf} \geq p_{gf}^m \cdot t_{h,gf}^s$	Price bands, $gf \notin FF$
$QB_{h,gf}(P_{h,gf} - p_{gf}^m \cdot t_{h,gf}^b) = 0$; $QS_{h,gf}(P_{h,gf} - p_{gf}^m \cdot t_{h,gf}^s) = 0$	
$P_{h,labor} = W$	Market wage
Input supply block	
$P_{h,input} = INPP_{input}$	Equalized price of inputs across households
$\frac{INPS_{input}}{INPS_{input,0}} = (INPP_{input})^{inpsupel_{input}}$	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	
$QP_a = b_a \prod_{f \in F} (FD_{a,f})^{\beta_{a,f}}$	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	
$\overline{TLS}_h = \left(\sum_{a \in A_1} \gamma_a \cdot (FD_{a,land})^{\rho_h^1} \right)^{1/\rho_h^1}$	CET land supply, top node ($\eta = 1$)
$FD_{node2,land} = \left(\sum_{a \in A_2} \gamma_a \cdot (FD_{a,land})^{\rho_h^2} \right)^{1/\rho_h^2}$	CET land supply, middle node ($\eta = 2$)
$FD_{node3,land} = \left(\sum_{a \in A_3} \gamma_a \cdot (FD_{a,land})^{\rho_h^3} \right)^{1/\rho_h^3}$	CET land supply, lower node ($\eta = 3$)
$\frac{R_{a,land}}{R_{a',land}} = \frac{\gamma_{h,a}}{\gamma_{h,a'}} \cdot \left(\frac{FD_{a,land}}{FD_{a',land}} \right)^{\rho_h^\eta - 1}$	CET optimality condition at every node η
$R_{\eta,land} = \left[\sum_{a \in A_\eta} (\gamma_a)^{\frac{1}{1-\rho_h^\eta}} \cdot (R_a)^{\frac{\rho_h^\eta}{\rho_h^\eta-1}} \right]^{\frac{1-\rho_h^\eta}{\rho_h^\eta}}$	Implicit rent at 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