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# MODELLING AGRICULTURAL DEVELOPMENT POLICY: A GENERAL EQUILIBRIUM APPROACH

by

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Abstract

A computable general equilibrium model is designed evaluating the economic impacts of agricultural policies such as price floors in food production, price ceilings in food consumption and in the use of agricultural inputs, and irrigation investments. Trade, sales tax, and external debt are also featured to assess their interactions with agricultural policies in fostering agricultural development.

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## 1. Introduction

There is growing awareness of the crucial importance of agricultural development to overall economic growth and stability in many developing countries (Eicher and Staatz, 1984; Mellor and Johnston, 1984; World Bank, 1986). However little is known about how agricultural sectors are affected by trade and macroeconomic policies and about how agricultural policies affect the whole economy. Our information on these matters is based largely on effective protection and domestic resource cost analyses (e.g. David, 1983) which describe poorly the resource allocation effects (Corden, 1967; Bhagwati and Srinivasan, 1973), and cost of policies.

In this paper we describe a computable general equilibrium model for evaluating the economic impacts of agricultural development policies in developing countries such as price supports, subsidies in the use of key agricultural inputs, and irrigation investments. Another use of the model is to analyze price ceilings in food consumption intended to promote a better income distribution. Not only can we evaluate the respective contributions of these policies to agricultural development, but also we can compare development strategies that rely on price interventions versus those that shift the supply curve through irrigation investments, a comparison previously done using a partial equilibrium framework (Barker and Hayami, 1976).

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The model also incorporates tariffs, export and domestic sales taxes in order to assess their impacts on agriculture and on the economy as a whole, as well as how these policies interact with agricultural policies. Tariffs and export taxes tend to discourage agricultural production by lowering the prices of exportable farm products and by raising the cost of imported inputs in agriculture, raising agricultural production subsidies. It is interesting to know whether a free trade regime could raise farm production more efficiently than subsidies. In the case of a cheap food policy, the question worth looking into is whether a free trade regime by encouraging the production of food items, most of which are exportables, could encourage food consumption through lower market prices of food products less costly than food subsidies.

The general equilibrium model described here is an extension of the Shoven-Whalley model to address the policy concerns just mentioned. In particular, we develop an Arrow-Debreu model of a small-open economy with homegoods, which features trade, domestic tax, and agricultural policies. A small-open economy framework with tariff policies was already developed in Clarete and Roumasset (1985). This was modified to accommodate nontariff trade barriers, rent seeking, and a Harris-Todaro labor market distortion in Clarete and Whalley (1985). We further extend this framework by adding price-fixing interventions and irrigation investments in agriculture, as well as sales taxes.

The general equilibrium treatment of price controls in a closed economy framework was modelled by Imam and Whalley (1982). We extend their approach by featuring the interactions of price controls with trade policies in a small-open economy model. We follow Imam and Whalley's treatment of price controls in the case of irrigation water which is a homegood in our model. However, in the case of tradables, excess demands are absorbed by the rest of the world, which implies public spending and deficit to defend price controls.

This raises the question of financing the deficit. In Kehoe and Serra, this deficit was funded by government debt from the domestic private sector. In our model, we also allow the government to incur a deficit but this is paid with public external debt. As in the Kehoe-Serra model, we do not feature debt repayment.

Existing computable general equilibrium models for analyzing agricultural policies (e.g. deJanvry and Subbarao, 1984; Bautista, 1984; Quizon and Binswanger, 1983) typically use the Johansen approach to applied general equilibrium analysis (Johansen, 1960).[1] As such, the method is susceptible

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[1] Concisely, this method is as follows. Consider (1) $F(x) = 0$ to be the complete set of general equilibrium relations, where $F$ represents a set of $n$ functions, $x$ is an $m$-dimensional vector and $0$ is an $n$-dimensional vector $(m > n)$. Then, (2) $Gy = 0$ is obtained by totally differentiating (1) with respect to $x$. Particularly, $G$ is an $n$-by-$m$ matrix of the partial derivatives of $F$ with respect to $x$, and $y = dx$. We assume that $G = [G_1 | G_2]$ where $G_1$ is $n$-by-$n$ and $G_2$ is $n$-by-$(m-n)$; further, we assume that $y = [y_1 | y_2]$ where $y_1$ is the vector of the changes in $n$ endogenous variables (the unknowns) while $y_2$ is the vector of the changes in $(m-n)$ exogenous variables (the shifters). Thus, (2) can be rewritten as $G_1y_1 + G_2y_2 = 0$. Assuming $G_1^{-1}$ exists, the solution to the model is (3) $y_1 = -G_1^{-1}G_2y_2$. deJanvry and Subbarao (1978) used the method by Dixon, Parmenter and Rimmer (1984) of piecewise calculations to minimize the linearization error in the Johansen approach.

to linearization errors unlike Shoven-Whalley models which use nonlinear, fixed-point algorithms. There is, however, a more fundamental concern about using the Johansen method. In the process of identifying the model, it is not uncommon that extraneous relationships to the basic Arrow-Debreu model are appended meddling the resulting welfare economic analysis. For example, the nonagricultural sectors of the economy were left out in the Quizon-Binswanger model. Monetary phenomena were featured in deJanvry and Subbarao (1984) who apparently treat money as neutral in the model. It should be pointed out however that this concern is not a necessary consequence of using the approach as demonstrated in Harberger (1962). Besides, this pitfall can also occur in models using nonlinear solution strategies (McCarthy and Taylor, 1978; Boadway and Treddenick, 1978; Dervis, de Melo and Robinson, 1982).

In the following section, we lay down the basic structure of our model. In Section 3 we introduce tariffs, sales taxes, and price controls. In Section 4, we introduce external debt. In Section 5, we add irrigation investments and subsidies to the model. Finally, potential applications and limitations of the model are summed up in Section 6.

## 2. A Small-Open Economy Model

Consider an economy consisting of $N$ producers, and $H$ consumers. Of the $N$ sectors (producers), some goods are not traded and comprise the set $SH$. All other goods are fully traded and make up the set $ST$. The economy is a price taker in its tradables. We denote the exogenous world price vector as $\bar{v}$.

Production is carried out under a decreasing returns to scale technology. Every producer utilizes $M$ variable factors, a sector-specific factor, and intermediate inputs. Denoting $X$ to be the output vector, $F$ to be the M-by-N factor demand matrix and $\overline{Z}$ to be the N-dimensional vector of fixed factors, we describe the $N$ production functions as: $X_j = f_j(F_j; \overline{Z}_j)$, $j = 1, \ldots, N$.

Under profit-maximization, one derives the $N$ supply functions,

$$(1) \qquad X_j = X_j(w, p; \overline{Z}_j), \qquad j = 1, \ldots, N,$$

where $w$ and $p$ are respectively the vectors of factor and producer prices, and the $M$ derived demands for factors in each of the $N$ sectors,

$$(2) \qquad F_{ij} = F_{ij}(w, p; \overline{Z}_j), \qquad i = 1, \ldots, M; \; j = 1, \ldots, N,$$

by taking the respective gradients of the $N$ restricted profit functions. Intermediate inputs are utilized in fixed proportion to production. We denote N-square matrix $A = [a_{ij}]$ to be the input-output matrix.

Economic rents are generated because of the presence of sector-specific factors. The respective rents in each sector are given by:

$$(3) \qquad \Pi_j = p_j X_j - \sum_{i=1}^{N} a_{ij} X_j q_i - \sum_{i=1}^{M} F_{ij} w_i \qquad j = 1, \ldots, N,$$

where $q$ is the N-dimensional vector of consumer or user prices. The distribution of these profits is assumed exogenous. This can be done by specifying how $\overline{Z}$ is distributed among consumers. To simplify our exposition, we introduce a set of exogenous share parameters, to be denoted by the $H$-dimensional vector $\sigma$, defining how the aggregate profit in the economy is to be divided.

Consumer preferences are described by $H$ utility functions, each a function of the final demand for goods: $U_h = U_h(C_h)$, $h = 1, \ldots, H$, where $U$ denotes the $H$-dimensional vector of utility indices and $C_h$ stands for the $N$-dimensional vector of final demands by consumer $h$. Under constrained utility maximization,

$$(4) \qquad C_{hj} = C_{hj}(q;\ Y_h) \qquad h = 1, \ldots, H;\ \ j = 1, \ldots, N,$$

where $Y_h$ is the income of consumer $h$. Summing up (4) across all consumers gives the vector of market demand curves, $C$.

The incomes of consumers come primarily from their endowments in variable and fixed factors. We assume that consumers are exogenously endowed with factors and derive income by selling these resources to firms. There is no tradeoff between leisure and market time in the model. Denoting $\overline{FS}$ to be the $H$-by-$M$ factor endowment matrix,

$$(5) \qquad Y_h = \sum_{i=1}^{M} w_i \overline{FS}_{ih} + \sigma_h \sum_{j=1}^{N} \Pi_j \qquad h = 1, \ldots, H.$$

The total supply of factor $i$ in the economy is $\overline{FS}_i = \sum_{i=1}^{H} \overline{FS}_{ih}$.

Although the total supplies of variable factors are fixed, their respective allocations across sectors are endogenous in the model.

Since the world prices of traded goods are fixed, we can define the following Hicksian (Hicks, 1936) composite quantities as in Clarete and Roumasset (1985):

$$(6) \qquad C_T = \sum_{j\epsilon T} \bar{v}_j(C_j + ID_j) \quad \text{and}$$

$$X_T = \sum_{j\epsilon T} \bar{v}_j X_j$$

where $ID_j$ is the total intermediate demand for good j. $C_T$ and $X_T$ are respectively the demand and supply for the composite good. According to the Hicks composite commodity theorem, goods with constant proportional prices can be aggregated in value terms and treated as one commodity.

By choosing a numeraire, we can scale the fixed world prices of traded goods with a scalar $r_T$, the domestic price of the composite commodity. If the chosen numeraire is a collection of homegoods, $r_T$ can be interpreted as the relative price of homegoods and traded goods or the real exchange rate, as in the special case involving two tradables and a homegood, the numeraire (Dornbusch, 1974). The domestic prices of traded goods are given by $p = r_T\bar{v}$.

Summing up (5) across all consumers and equating the total with aggregate expenditures of consumers, and using (3), and (6), we obtain the following expression of Walras' Law:

$$(7) \qquad \sum_{i=1}^{M} w_i\left(\sum_{j=1}^{N} F_{ij} - \overline{FS}_i\right) + \sum_{j\epsilon SH} p_j(C_j + ID_j - X_j) + r_T(C_T - X_T) = 0.$$

Thus, general equilibrium for this basic formulation of a small-open economy is the set of equilibrium prices of homegoods, factors, and of the composite commodity which clear all markets of homegoods and factors and simultaneously satisfy trade balance.

Note that there are no wedges between producer and consumer prices as well as between domestic and world prices in the model. In the following section, we introduce the government that taxes imports, exports, domestic sales, and imposes price controls on a subset of traded commodities.

3. Price Interventions, Tariff Policies, and Sales Taxes

A price-distorting government is now added into the model, imposing price ceilings on consumer and intermediate goods as well as price floors in producing a subset of traded goods. We denote STC to be the subset of traded goods under price ceiling policies and STF as the set of traded goods under price floors in producing a subset of traded goods. An intersection of STC and STF is allowed. Any excess demands arising from these pricing policies are absorbed by the rest of the world. Hence, no rationing is done in response to such policies.

The subsidy cost of price interventions is fully borne by the government. To pay for the subsidy, the government imposes tariffs on imports, and taxes exports and domestic sales. We denote t to be the vector of tariff (or export tax, if negative) rates and tx to be the vector of sales tax rates.

The domestic price received by producers is given by:

$$
(8) \qquad P_j = \begin{cases} \max[\bar{p}_j, r_T \bar{v}_j (1 + t_j)], & \text{if } j \in STF; \\ \bar{p}_j, & \text{if } j \in SH; \text{ and} \\ r_T \bar{v}_j (1 + t_j), & \text{otherwise,} \end{cases}
$$

where $\bar{p}$ is the vector of price floors. The total amount of production subsidy (PS) is:

$$
(9) \qquad PS = \sum_{j \in STF} [P_j - r_T \bar{v}_j (1 + t_j)] X_j .
$$

The domestic price paid by consumers is given by:

$$
(10) \qquad q_j = \begin{cases} \min[\bar{q}_j, r_T \bar{v}_j (1 + t_j)(1 + tx_j)], & \text{if } j \in STC; \\ P_j (1 + tx_j) & \text{if } j \in SH; \text{ and} \\ r_T \bar{v}_j (1 + t_j)(1 + tx_j), & \text{otherwise} \end{cases}
$$

where $\bar{q}$ is the vector of price ceilings. The total consumption subsidy (CS) is:

$$
(11) \qquad CS = \sum_{j \in STC} [r_T \bar{v}_j (1 + t_j) - (\frac{q_j}{1 + tx_j})](C_j + ID_j).
$$

Note the interactions between price intervention and trade policies in the model. By varying the vector t, the policymakers can affect the amount of subsidies. Increasing tariff rates or lowering export tax rates, for example, tends to reduce production subsidies by decreasing the wedge between the floor price and marginal cost. In contrast, the same policy measures tend to increase consumption subsidies by raising the difference between marginal cost and the ceiling price.

The revenues from trade taxes (TR) and from sales taxes (CR) are given by:

$$(12)\quad TR = \sum_{j \in ST} r_T \bar{v}_j t_j (C_j + ID_j - X_j);\ \text{and}$$

$$CR = [\sum_{j \in STC} \frac{q_j tx_j}{(1 + tx_j)} + \sum_{j \in SH} p_j tx_j + \sum_{j \in TNC} r_T \bar{v}_j (1 + t_j) tx_j ](C_j + ID_j)$$

where TNC denotes the set of traded goods with uncontrolled prices.

The fiscal surplus of the government is defined as:

$$(13)\qquad D = TR + CR - CS - PS.$$

We assume that the surplus is given back to consumers in a lump-sum fashion as transfer payments, denoted by TY. We further suppose that the H-dimensional vector of share parameters, $\phi$, which describes how TY is to be distributed to all consumers in the model is known.

Accordingly, the income of consumer h is modified to reflect the transfer payment received by him from the government. Equation (5) becomes

$$(5b)\qquad Y_h = \sum_{i=1}^{M} w_i \overline{FS}_{ih} + \sigma_h \sum_{j=1}^{N} \pi_j + \phi_h TY, \qquad h=1,\ldots,H.$$

Adding up (5b) across all consumers, equating the result to the total expenditures of consumers in the model, and making use of equations (3), (6), (8) through (13), we obtain the following expression of Walras' Law, the derivation of which is detailed in the Appendix:

$$\text{(7b)} \quad \sum_{i=1}^{M} w_i \left( \sum_{j=1}^{N} F_{ij} - \overline{FS}_i \right) + \sum_{j \in SH} p_j (C_j + ID_j - X_j)$$

$$+ r_T (C_T - X_T) + (D - TY) = 0.$$

General equilibrium for this formulation will be the set of factor prices, homegood prices, $r_T$, and the transfer payment (or lump-sum tax if $D < 0$) which clears all markets of factors and homegoods and balances the trade and public sector accounts. Formally, we solve the following simultaneous equation set for $w$, $p_j (\forall j \in SH)$, $r_T$ and $TY$:

$$\text{(14)} \quad \sum_{j=1}^{N} F_{ij} - \overline{FS}_i = 0, \qquad i = 1, \ldots, M;$$

$$C_j + ID_j - X_j = 0 \qquad \forall j \in SH;$$

$$C_T - X_T = 0; \text{ and}$$

$$D - TY = 0.$$

## 4. Public Foreign Debt

In Section 3, we added price controls, tariff policies, and sales taxes to the model. We let the real exchange rate fully adjust so that the government can balance its budget. However, governments in LDCs typically borrow externally in order to fund their balance of payments deficits. In this section, we feature foreign borrowing of the public sector.

We suppose that the government can sell public bonds to the rest of the world at unit prices. One unit of public bond is equal to one unit of foreign exchange borrowed or foreign credit. Since the country is small, the world demand for such bonds is perfectly elastic at the given world marginal cost of credit. To simplify, we assume that the marginal cost of lending to the small country is zero. Furthermore, due to the static nature of the model, the maturity date of the credit is unspecified. These simplifying assumptions imply that foreign credit is practically a transfer to the economy from the rest of the world.

Anticipating a fiscal deficit, the government sells bonds to the world the amount of which is equal to the expected deficit. Foreign creditors buy up all such bonds. We denote $B$ to be the amount of bonds sold and $L$ to be the amount of foreign credit. Thus $B - r_T L = 0$.

Adding $B - r_T L = 0$ to equation (7b) and noting that $TY$, the anticipated fiscal surplus to be transferred back to consumers, is equal to zero, we come up with the following expression of Walras' Law:

$$\text{(7c)} \qquad \sum_{i=1}^{M} w_i \Big( \sum_{j=1}^{N} F_{ij} - \overline{FS}_i \Big) + \sum_{j \in SH} p_j (C_j + ID_j - X_j)$$

$$+ r_T (C_T - X_T - L) + (D + B) = 0$$

The relevant general equilibrium conditions with foreign borrowing are:

$$\text{(15)} \qquad \sum_{j=1}^{N} F_{ij} - \overline{FS}_i = 0, \qquad i = 1, \ldots, M;$$

$$C_j + ID_j - X_j = 0 \qquad \forall j \in SH;$$

$$r_T (C_T - X_T - L) = 0; \text{ and}$$

$$D + B = 0.$$

The last two equalities are respectively the balance of payments and the balanced budget equilibrium conditions. The balance of payments condition states that the actual trade deficit is equal to the public foreign debt. The balanced budget condition states that the actual and anticipated fiscal deficits are equal. Equation (15) is to be solved for $w$, $p_j (\forall j \in SH)$, $x_T$ and B.

5. Irrigation Investments and Subsidies

To introduce irrigation investments, we create a market for irrigation water. Consider now that irrigation water is added as the $(N + 1)^{th}$ sector of the model. Accordingly, we expand the dimension of the N-dimensional price vectors in the model to accommodate the price of irrigation water. We denote IRR to be the set of irrigated sectors (crops).

The demand for irrigation water is derived from the marginal product of water in irrigated crops. Formally, the production functions of these crops incorporate irrigation water as an additional input:

$$(15) \qquad X_j = g_j(F_j, WD_j; \overline{Z}_j), \qquad \forall j \in IRR,$$

where $g_j$ is a decreasing-returns-to-scale function and $WD_j$ is the use of irrigation water in the irrigated sector j. In (15), we allow for substitution between $WD_j$ and the variable factors to occur. Under profit maximization, the derived demand for irrigation water is:

$$(16) \qquad WD_j = WD_j(w, p, q_i; \overline{Z}_j), \qquad \forall j \in IRR; \quad i = N + 1$$

Certainly, water is required by all crops. The difference is that in nonirrigated crops water is provided only by nature. Since the model is non-stochastic, we assume that the amount and distribution of natural (as opposed to irrigation) water are exogenous for the duration of the analysis.

Accordingly, natural water is incorporated in $\bar{Z}_j$. With irrigation, irrigated crops can vary the use of water, using the market of irrigation water, while continuing to utilize the natural water as a fixed input.

We suppose that the production of irrigation water can be represented by a production function which transforms variable factors and a sector-specific factor into water: $WS = f_j(V_j;\bar{Z}_j)$, where f is a decreasing-returns-to-scale function and j denotes irrigation water. Under profit maximization,

$$(17) \qquad WS = WS(p,w;\bar{Z}_j) \qquad\qquad j = \text{irrigation water}$$

which is the supply function of irrigation water. Note that the p vector has as its $(N+1)^{th}$ element the marginal cost of providing irrigation water.

The link between irrigation investments and water provision is channeled through the fixed input, $\bar{Z}_j$, in (17), which represents mostly the fixed capital that irrigation investments underwrite. Irrigation capital in turn may take various forms such as an irrigation dam or a system of canals for distributing irrigation water to various farm plots. An exogenous increase in irrigation investments will expand the stock of irrigation capital and accordingly will shift the supply curve in (17) outward.

The extent of the shift depends upon the nature of irrigation investments. One of the leading irrigation policy issues at present is to determine whether constructing irrigation dams or improving the management of existing irrigation systems will expand more the supply of irrigation water. For our purposes, we assume that the technical information about the relationship between the nature and extent of irrigation investments and the supply of irrigation water can already be provided by engineers.

In order to focus on the tradeoff between investment in irrigation and other policies to increase the available supply of food, one needs to abstract from issues of water management. We assume that any inefficiencies in management are already built into the production function. Subsidies to irrigation are measured as the difference between the charge per unit of water and the long-run marginal cost of delivering water. Since we are abstracting from issues of information and enforcement costs, it does not matter whether the institutional mechanism for water charges is a price per unit or whether quantities of water are centrally determined and farmers charged a lump sum. In either case, farmers are assumed to use water up to the point where the marginal product of water equals the user cost, $q_j$.

Since water is a homegood, our analysis of the water subsidy follows closely that in Imam and Whalley (1982). Suppose now that $\bar{q}_j$, j = irrigation water, is the price ceiling of irrigation water set by policymakers. Formally, the user price of irrigation water is given by:

$$(18) \qquad q_j = \min([\bar{q}_j, p_j(1 + tx_j)]), \qquad j = \text{irrigation water}.$$

Substituting (18) into (16) and summing up the result across all irrigated crops, we get the market demand for irrigation water.

If producers would receive $\bar{q}_j$, then an excess demand for water would arise and could be resolved through rationing. However, this would constrain rather than encourage the use of irrigation water and thus would defeat the purpose of this price ceiling policy.

Hence, producers are subsidized to produce more water to cover the excess demand for it. The endogenous <u>ad valorem</u> subsidy rate is:

$s_j = p_j - \frac{q_j}{(1 + tx_j)}$, j = irrigation water. The price $p_j$ in turn is the solution of (18) such that WS is equal to the market demand for irrigation water. The cost of the irrigation program is:

(19) $$IS = \sum_{j \in IRR} s_j WD_j(q_i, p, w; \bar{Z}_j) + IC, \qquad i = \text{irrigation water}$$

where IC is the amount of public funds invested in building irrigation systems. Equation (19) is subtracted from (13), modifying the fiscal surplus in the model.

The following excess demand function for irrigation water is added to the equation set in (14) and is to be solved for the marginal cost of irrigation water.

(20) $$WD_j - WS = 0.$$

## 5. Potential Applications and Limitations

The general equilibrium model designed here can be used to evaluate the economic impacts of agricultural policies, such as price floors in food production, price ceilings in food consumption and in the use of agricultural inputs, and irrigation investments. We can also use the model to compare two-tier pricing policies and irrigation investments as tools for improving income distribution and food consumption in developing countries. Previous comparisons (e.g., Barker and Hayami, 1976), have utilized partial equilibrium formulations.*

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*Barker and Hayami (1976) also used government expenditures as the basis of their comparison instead of true economic costs.

Furthermore, since the model features agricultural as well as trade and tax policies, we can use it to assess the relative efficiencies of these instruments to foster agricultural development. In particular, we can estimate the production effects and the economic costs of a regime of farm subsidies and indirect discrimination via import protection relative to a regime of free trade. Also, we can assess if free trade policy by encouraging the production of exportable food items, is a better instrument to encourage food consumption than food subsidies. For those interested in agricultural implications of measures which raise tax revenues, the model can be used to compare the relative waste of tariffs and domestic sales taxes.

The model is also potentially useful in computing constrained optimal values of policy instruments within the control of the policy-making bodies in question, taking the other policy variables as politically fixed. In this case, the analyst solves for the values of the flexible policy instruments that maximize real national income subject to the fixed policy variables. In practice, this analysis may involve the following. Given a finite set of policy options to offset the inefficiency and undesired consequences of politically fixed policy distortions, the analyst uses the model to compare discretely his alternative strategies; the option which gives the largest net increment to real national income is chosen as the second-best agricultural policy.

As is always true in applying abstract models, it is important to bear in mind what phenomena are left out. The model does not incorporate disequilibrium, the process of adjustment, induced investment, or exogenous disturbances that may occur during a period of adjustment. Accordingly, the model should not be used as a predictive tool, except as a point of departure. It has been designed primarily to assess the efficiency and equity consequences of alternative policies, not to predict the actual path of adjustment.

The model also does not attempt to incorporate transaction costs and the forms of economic organization that would be necessary for a more realistic analysis of agricultural policy issues. For example, our treatment of irrigation water as an ordinary commodity with a well-developed market of its own abstracts from property rights problems with regard to natural sources of water and enforcement problems of irrigation fee collections. Hence, our approach here is best regarded as a limited approximation of the actual allocation mechanism for irrigation water. Despite these limitations, the quasi-open economy model developed here provides a natural starting point for evaluating trade-offs among price-distortions, quantity controls, and investment policy. We believe that the model is a potentially useful tool, if not applied in an overly rigid and mechanistic fashion, for informing policy dialogues on agricultural development strategy.

## Appendix

The effective budget constraint of the community is:

$$\sum_{j=1}^{N} q_j C_j - \sum_{h=1}^{H} [\sum_{i=1}^{M} w_i \overline{FS}_{ih} + \sigma_h \sum_{j=1}^{N} \pi_j + \phi_h TY] = 0.$$

Substituting equation (3), the definition of $\pi_j$, we get:

$$\sum_{j=1}^{N} q_j C_j - \sum_{i=1}^{M} w_i \overline{FS}_i - \sum_{j=1}^{N} [p_j X_j - \sum_{i=1}^{N} a_{ij} X_j q_i - \sum_{i=1}^{M} w_i F_{ij}] - TY = 0.$$

This simplifies to:

$$\sum_{i=1}^{M} w_i [\sum_{j=1}^{N} F_{ij} - \overline{FS}_i] + \sum_{j \in SH} q_j (C_j + ID_j) - \sum_{j \in SH} p_j X_j$$

$$+ \sum_{j \in STC} q_j (C_j + ID_j) + \sum_{j \in NTC} q_j (C_j + ID_j)$$

$$- \sum_{j \in STF} p_j X_j - \sum_{j \in NTF} p_j X_j - TY = 0.$$

Using equations (8) and (10), the definitions of domestic consumer and producer prices, and adding and subtracting: (a) $r_T \bar{v}_j (1 + t_j)(C_j + ID_j)$, if $j \in STC$, and (b) $r_T \bar{v}_j (1 + t_j) X_j$, if $j \in STF$, we get:

$$\sum_{i=1}^{M} w_i (\sum_{j=1}^{N} F_{ij} - \overline{FS}_i) + \sum_{j\in SH} p_j (C_j + ID_j - X_j)$$

$$+ \sum_{j\in SH} p_j tx_j (C_j + ID_j) + \sum_{j\in ST} r_T \bar{v}_j (C_j + ID_j - X_j)$$

$$+ \sum_{j\in ST} r_T \bar{v}_j t_j (C_j + ID_j - X_j)$$

$$- \sum_{j\in STC} [r_T \bar{v}_j (1 + t_j) - q_j](C_j + ID_j)$$

$$+ \sum_{j\in NTC} r_T \bar{v}_j (1 + t_j) tx_j (C_j + ID_j)$$

$$- \sum_{j\in STF} (p_j - r_T \bar{v}_j (1 + t_j))X_j - TY = 0.$$

Multiplying $q_j$ with $(1 + tx_j)/(1 + tx_j)$ if $j \in STC$ and using (6), the definition of the Hicksian composite good, we get:

$$\sum_{i=1}^{M} w_i (\sum_{j=1}^{N} F_{ij} - \overline{FS}_i) + \sum_{j\in SH} p_j (C_j + ID_j - X_j)$$

$$+ r_T (C_T - X_T) + \sum_{j\in ST} r_T \bar{v}_j t_j (C_j + ID_j - X_j) - \sum_{j\in STC} (r_T \bar{v}_j (1+t_j) - \frac{q_j}{(1+tx_j)} (C_j + ID_j)$$

$$+ \sum_{j\in STC} \frac{q_j tx_j}{(1+tx_j)} (C_j + ID_j) + \sum_{j\in NTC} r_T \bar{v}_j (1 + t_j) tx_j (C_j + ID_j) + \sum_{j\in SH} p_j tx_j (C_j + ID_j)$$

$$- \sum_{j\in STF} (p_j - r_T \bar{v}_j (1+t_j))X_j - TY = 0.$$

Finally, using (9), (11), (12) and (13), respectively, the definitions of production subsidy, consumption subsidy, tariff revenue, sales tax revenue, and fiscal surplus, we derive equation (7b).

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