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IMPACT MULTIPLIER POLICY MODELS FOR THE AGRICULTURAL SECTOR: AN APPLICATION TO INDIA

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This paper discusses a relatively simple type of general equilibrium policy model and illustrates its application to Indian agriculture. The "impact multiplier" (IM) model discussed here is based on differential calculus and is suitable to comparative static policy analysis. It may be contrasted with the "computable general equilibrium" (CGE) model discussed by C. Habito elsewhere in this issue. The CGE model is better suited to certain types of dynamic analysis and to the analysis of large changes and distortions. The chief weakness of either the IM or CGE type models in practice is that they are often not based on solid econometric estimates. A related weakness is that they are often highly inflexible in imposing substitution parameters that are either zero or constant. The CGE models, for example, are often "calibrated" rather than estimated by imposing Cobb-Doublas technology for the production of goods, with no possibilities for substitution between products.

This is a serious flaw for the agricultural sector where a great deal of substitution between crops can take place. The production of rice in India, for example, is sensitive not only to its own price but to the price of wheat, sorghum and other crops. In principle, CGE models can handle these substitution possibilities but practice lags behind principle at this point. The IM models, on the other hand, have been a little more flexible in this matter although they too have not always been specified from series econometric estimates.

In section I of this paper I sketch the essentials of the I-M model. Section II reports estimates of the agricultural producer core of the model. Section III illustrates its application to several policy questions in India.

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I. Model Overview

The central part of the model is the producer core. This is a system of variable output supply and variable factor demand equations (see section II of the overview paper and the paper "Output Supply and Factor Demand in Philippine Agriculture" for estimates of a producer core for Philippine agriculture). The system is derived from a system of maximized profits functions. For the Indian case the system includes four output supply equations (wheat, rice, coarse cereals, and other crops) and four variable factor demand equations (labor, bullock labor, tractors, and fertilizer).

(1a) Output $Y_i = Y_j\ (P, R, F, Z, t)$

(1b) Input $X_j = X_j\ (P, R, F, Z, t)$

where

Y_i = the output supply equation

X_j = the input demand equation

P = the vector of output prices

R = the vector of input prices

F = the vector of fixed term factors

Z = a vector of "infrastructure" variables

t = a time index

Differentiating equations (1a) and (1b) and expressing them in time rates of change, we obtain[1]

1. That is, $\dot{Y}_i = (\partial Y_i / \partial t)\ (1/Y)$. I will also simplify the summation notation as follows:

$$\sum_{i=1}^{n} = \sum_{i}.$$

$$(2a) \quad \dot{Y}_i = \Sigma_n B_{in} \dot{P}_n + \Sigma_m B_{im} \dot{R}_m + \Sigma_z B_{iz} \dot{Z}_z + \dot{B}_i$$

$$(2b) \quad \dot{X}_j = \Sigma_n B_{jn} \dot{P}_n + \Sigma_m B_{jm} \dot{R}_m + \Sigma_z B_{jz} \dot{Z}_z + \dot{B}_j$$

In equations (2a) and (2b) the B_{in}, etc., are elasticities of output supply (or factor demand) with respect to the relevant price or other variable.

Notice that

$$(3a) \quad \dot{B}_i = (-\partial Y_i/\partial t)\ (1/Y_i)$$

$$(3b) \quad \dot{B}_j = (-\partial X_j/\partial t)\ (1/X_j)$$

and these can be interpreted as productivity "shifters" or output and factoral rates of productivity change.

Now add to these the producer core output demand equation (4a) and factor supply equation (4b), also expressed in rates of change.

$$(4a) \quad \dot{Y}_i = \Sigma_n \alpha_{in} \dot{P}_n + \alpha_{it} \dot{I} + \dot{Y}_i^*$$

$$(4b) \quad \dot{X}_j = \Sigma_m E_{jm} \dot{R}_m + \dot{X}_j^*$$

In equation (4a) the α_{in} are demand elasticities, α_{iI} is an income elasticity, and $\dot{Y}_i^*$ depicts an exogenous shifter of the ith demand function (e.g., population growth).

In equation (4b) the E_{jm} are supply elasticities and the $\dot{X}_j^*$ are exogenous supply shifters (e.g., a subsidy).

Nonagricultural prices are presumed to be unaffected by the policy changes that impact on the agricultural sector (cross elasticities between agricultural and nonagricultural prices are assumed to be zero). Nonagricultural incomes affect demand equation (4a). The consumer price index is computed from different population groups using consumption weights for each group (see below).

Labor migrates between the agricultural and nonagricultural sector in response to changes in the relative wage. Wages also affect labor supply through the labor-leisure choice. Growth in population affects labor supply $(\dot{X}_j^*)$ as well as demand $(\dot{Y}_i^*)$.

Land rents are derived residually as the difference between profits (calculated as the value of output minus the value of variable factors –

not sales). This presumes that markets exist for these commodities.

The system of equations can be expressed in matrix form as:

$$\begin{bmatrix} B_{11}-\alpha_{11} & B_{12} \cdots B_{1,n+m} \\ \vdots & \\ B_{n+1,1} \cdots & B_{n+1,n+m}-E_{n+1} \\ \vdots & \\ B_{n+m,1} \cdots & B_{n+m,n+m}-E_{n+m} \end{bmatrix} \begin{bmatrix} \dot{P}_1 \\ \vdots \\ \dot{R}_1 \\ \vdots \\ \vdots \end{bmatrix} = \begin{bmatrix} \alpha_{1I}\dot{I}-\Sigma_z B_{iz}\dot{Z}_z + \dot{Y}_1 \\ \vdots \\ -\Sigma_z B_{n+1,z}\dot{Z}_z + X^*_{n+1} \\ \vdots \\ \vdots \end{bmatrix}$$

$$[G] \cdot [P] = [D^*]$$

where the G matrix is the sum of the input demand, output supply matrix and the negative of the input supply/output demand elasticity matrix. It is thus an excess elasticities matrix.

To calculate the impact of the policy variables in D^* on equilibrium prices, we require:

(a) Estimates of policy actions on D^*

(b) The inverse of the G matrix

$$[P] = G^{-1}[D^*]^*$$

Note that this expression for change in prices is exact for small changes but not necessarily for large changes.

After calculating the change in $[P]$ we can calculate the change in endogenous quantities as well.

This model (as well as the CGE model), then, has a good deal of promise for policy analysis. It is also terribly vulnerable to misuse. its promise lies in its capacity to produce changes in prices and quantities due to a specific change in a policy variable in $[D^*]$. This promise is greatly enhanced when these changes in prices and quantities can be used to calculate changes in real incomes (as in the Indian model). It is further enhanced when these real income evaluations can be made for specific population groups, enabling distributional implications to be drawn. (In the Indian case, real income calculations are made for five population groups.)

These models are vulnerable to misuse in many ways. Ad hoc estimates of the G matrix elasticities may be used. Poorly designed or impossible policy experiments may be made. (For example, the analyst may simulate a change in an infrastructure variable ($\dot{Z}_z$ in 2_a, 2_b) and be quite wrong because the B_{iz} elasticities are not known.) Model components have to be very carefully scrutinized if one is to use such models.

II. The Indian Model: Parameter Estimates

An IM model for India was developed by Binswanger and Quizon (1985). The components were based on the following studies:

(a) The producer core was estimated by Evenson (1982) for North India.
(b) The consumer demand core was estimated by Swani and Binswanger (1983).
(c) The migration function was estimated by Dhar (1981).
(d) The labor supply function was estimated by Rosenzweig (1984.)

This illustrates the flexibility of the IM model as regards sources of econometric estimates. Because these estimates were obtained from different data sets, it would be next to impossible to estimate all of the parameters in the *G* matrix from a single data set. Quizon and Binswanger made minor adjustments to insure convexity in the overall matrix.

Because of the importance of the producer core to the model, I will report these estimates in some detail. These estimates were undertaken in two stages. This was done to develop a long- and short-run policy perspective. The short-run stage entailed the estimation of a system of four variable output and four variable factor equations derived from variable profit functions. Several infrastructure variables were incorporated into these equations. A long-run stage specified the determinants of changes in these infrastructure variables. Population density was an important determinant of changes in infrastructure and thus affected the producer core.

Consider first the short-run stage. The short-run estimates were obtained using district level data from the states of Punjab, Haryana, Uttar Pradesh, and Bihar. These districts can be grouped into two major groups: a primarily wheat producing area (Punjab, Haryana and Western Uttar Pradesh) and a primarily rice producing area (Eastern Uttar and Bihar). Table 1 provides a variables dictionary for the data set and reports means for the two areas.

In Table 1, a short description of the definition of each variable is provided. The variables are also classified as variable farm outputs, variable farm inputs, prices, and structure variables.

Table 2 reports elasticities computed at the means of the data for the eight equations. By reading down each column one obtains the elasticity effects of each price and structure variable on the output supply or input demand variable in question. For example, in the first column we can see the estimated effects on wheat supply of the wheat price, the rice price, etc., all the way down to the research variable. (All statistically significant variables are indicated by asterisks.) We note that the wheat supply elasticity with respect to its own price is 0.370. This means that a 10 percent increase in the wheat price, holding all other prices and structural variables constant, will cause a 3.7 percent increase in the supply of wheat. We can also see the consequences of a wheat price increase, holding everything else constant, not only on wheat supply but on the demand for fertilizer, bullock labor, tractors, and labor by reading across the wheat price row in the table. We thus find that a 10 percent increase in the price of wheat causes a 3.7 percent increase in the quantity of wheat supplied, a 2.07 percent decrease in the quantity of rice supplied, a 2.24 percent increase in the quantity of coarse cereals supplied, etc.

Our a priori expectations of the sign and magnitude of these elasticities are borne out by these data with only one exception. We expect all own-price elasticities of supply to be positive, and they are. We expect the own-price elasticities of demand for inputs to be negative; they are, with the exception of fertilizer demand. Only the labor demand elasticity is significant. The cross-price effects are generally as expected. In the output block, when a cross-price elasticity is negative it means hat the crops are "substitutes." We note that wheat and rice and other crops and coarse cereals are good substitutes. Interestingly, we note that wheat and coarse cereals are "complements," i.e., an increase in the price of one of the pair induces an increase in the supply of both. This can happen when the two crops fit well together in an annual rotation.

Within the input block, negative cross-elasticities indicate that the inputs pairs are substitutes. Our data show that fertilizer may be a complement to labor and to tractors.

Perhaps of most interest, however, are the "structure" shifters. Our results indicate that rural electrification biases the output mix in favor of coarse cereals and other crops. It biases input demand in favor

TABLE 1

VARIABLES DICTIONARY: NORTH INDIAN DATA SET OBSERVATIONS ON 22 REGIONS, 1959-74

Variable Definitions	Means Wheat Region	Rice Region	All
1. Variable Farm Outputs			
Wheat	20678.19	10124.76	16360.88
Rice	4319.35	22083.35	11586.44
Cereal Grains	5660.20	4467.06	5172.10
Other Crops	25833.99	16114.35	21867.78
2. Variable Farm Inputs			
Labor	22006.25	41818.24	30111.16
Animal Power	21841.10	50139.95	33417.90
Tractor Services	1038.04	256.74	718.42
Fertilizer	4155.17	2641.76	3536.05
3. Prices			
Wheat	2.215	2.291	2.246
Rice	2.058	1.879	1.984
Cereal Grains	2.174	2.390	2.262
Other Crops	2.898	3.288	3.058
Labor	2.041	2.111	2.070
Animal Power	1.790	1.371	1.619
Tractor Services	1.577	1.577	1.577
Fertilizer	1.278	1.307	1.290
4. Structure Variables			
Rural Electrification (percent of villages electrified)	38.99	15.25	29.28
Roads (km of roads per 10 km^2)	2.08	1.11	1.68
Research Expenditures (cumulative expenditures, 1955 to t-2)	9.56	4.61	7.54
Research Intensity (current expenditures/net cropped area)	1.49	.865	1.23
High Yielding Varieties (percent of gross cropped area under high yielding varieties of rice, wheat and maize)	10.79	7.09	9.27
Irrigation Intensity (percent of gross cropped area irrigated)	40.79	25.31	34.57
Net Cropped Area (000 hectares)	1299.03	1711.52	1467.78
Farm Size (net cropped area/ number of cultivators)	.0017	.0012	.0015
Agricultural laborers/Cultivators	.265	.430	.332
Literacy (percent of rural males who are literate)	25.80	27.13	26.34

TABLE 2

ELASTICITY ESTIMATES: NORTH INDIAN DISTRICT DATA SET 1959-1975

Elasticity with Respect to:	Elasticities of Output Supply				Elasticities of Input Demand			
	Wheat	Rice	Coarse Cereals	Other Crops	Fertilizer	Bullock Labor	Tractors	Labor
Wheat Price	.370**	−.128**	.073*	−.058	.001	−.025	.001	−.232**
Rice Price	−.207**	.392**	−.040	−.090	.042*	−.019	.003	−.079
Coarse Cereals Price	.224*	−.076	.040	−.227*	.062	.025	−.011	−.038
Other Crops Price	−.031	−.030	−.040*	.176**	−.024**	.005	.001	−.046
Fertilizer Price	−.007	−.198*	−.155	.348**	.195*	−.440**	.038	.217**
Bullock Price	.016	.008	−.005	.006	−.038**	−.010	−.001	.023**
Tractor Price	.010	−.051	.112	−.016	.160	−.010	−.084	−.103
Labor Price	.001	−.060**	.093**	.011	.122**	.048**	−.155**	−.061**
Electrification	−.025	.011	.057*	.084**	.245**	.006**	.034	−.026**
Roads	−.110	−.465**	.373**	−.362**	−.325**	−.086**	.291*	.029
Rainfall	.161**	.407**	−.173*	.019	.456	.012	.208*	.055**
Irrigation Int.	1.123**	.271*	.919*	.276**	1.203**	.056**	1.861**	.117**
Net Cropped Area	−.139	1.485**	1.048**	.609**	.289	−.022	−1.266**	.042
Farm Size	.224*	.379**	−.027	−.210**	−.744**	.060**	.693**	−.285**
HYV's	.278**	.109**	−.074**	−.128**	.259**	.012*	−.122**	.030*
Indian Research	.023	−.085**	−.102**	.176**	.249**	−.022	.537**	−.084**

*Asymptotic "t" < 2.0 > 1.5
**Asymptotic "t" > 2.0

of fertilizer and against labor. Roads, on the other hand, create biases in favor of coarse cereals and against other crops and are biased against fertilizer and in favor of tractor demand. It should be noted, however, that this variable and perhaps others may be reflecting geographic factors, and we should not presume therefore that it is easily subject to policy manipulation. The rainfall variable is a strictly geoclimatic variable, and it is not subject to policy modification.

Irrigation intensity and net cropped area, on the other hand, are subject to policy manipulation. Increased investment increases all outputs and inputs, but is quite clearly biased toward wheat and coarse cereals on the output side and toward fertilizer and tractor use on the input side. As the net cropped area in the typical district expands, holding farm size constant, it becomes biased in favor of rice and coarse cereals and against wheat. It increases the demand for fertilizer, but decreases the demand for tractors. An increase in average farm size, holding total net cropped area constant, on the other hand, is biased against rice and favors other crops, fertilizer and tractor demand. It is also biased against labor employment. Conversely, a decrease in farm size would reduce the demand for fertilizer and tractors and increase the demand for labor.

Much has been written about the "Green Revolution" and the general technical advance in India. The general presumption of much of the literature is that the introduction of high-yielding varieties did not have biases on the input side, though it was clearly biased in favor of wheat and rice. It also quite clearly shows that when high-yielding wheat and rice varieties are made available the supply of coarse cereals and other crops is reduced. The results also show a bias in favor of fertilizer on the input side.

The Indian agricultural research system, on the other hand, has a strong bais in favor of other crops. It also appears to have quite strong biases on the input side. It produces a technology that is fertilizer- and tractor-using and labor-saving. It is important to note here that most of the high-yielding varieties in the HYV variable are actually Indian varieties (see Table 6). In the early period of adoption of HYVs, wheat and rice varieties were imported (from CIMMYT and IRRI), but after this initial adoption these varieties were replaced by Indian-bred varieties. Thus, the inclusion of the HYV variable in the same equations with the Indian research variable requires a rather specialized interpretation for the Indian research variable. Specifically, it refers to the technology associated with the non-HYV crops (rice, wheat, coarse cereals) and the nonvarietal technology for the HYV crops.

With this in mind, we can better appreciate the elasticities associated with the Indian research variable. It is not surprising that it has a high elasticity effect on the supply of other crops and negative elasticities on those crops that are reasonable substitutes for other crops, i.e., coarse cereals and rice. The fact that Indian research creates a bias in favor of fertilizer use and mechanization is also reasonable given that it is primarily nonvarietal technology that is being produced.

The full effect of Indian research is best seen by looking at the combined effect of HYVs and Indian research.

It is of interest to compare the effect of some of the structural variables on aggregate output and input use. The elasticity of the total output, total input and variable factor productivity computed from Table 2 is summarized in Table 3.

TABLE 3

ELASTICITIES OF OUTPUT, INPUT AND PRODUCTIVITY WITH RESPECT TO STRUCTURAL VARIABLES

	Total output	Total input	Total variable productivity
Electrification	.03357	–.00859	.04216
Irrigation intensity	.58752	.23477	.35275
Net cropped area	.61071	–.04438	.65509
Farm size	.06043	–.16189	.22232
HYV's	.04796	.02265	.02531
Indian research	.04929	–.02037	.06966

The long-run stage entailed an estimation of the determinants of infrastructural change or investment. For fixed farm factors this estimation could have been treated in a dynamic model (see Lopez 1985), and investment equations could have been added to the base profits functions model. However, for most infrastructural variables investment and change decisions are made by government and nonfarm firms. Many are the outcomes of long-run processes. One of the most important of these is population density.

An influential book by Esther Boserup, *Conditions of Agricultural Growth* (1905), makes this point forceful. Boserup discussed the changes in agricultural organization and the crop cultivation techniques that accompanied population growth in Africa. She noted that population growth induced changes in fallow systems from swidden and long fallow systems to annual and multiple cropping systems. These changes were accompanied by new cultivation techniques and "investments" in land and irrigation.

Julian Simon is a stronger advocate than Boserup of population-induced investments and technical change. He argues that the "Verdoorn" effect (i.e., that output demand expansion causes productivity gains) is important in most economies and that population growth induces agricultural investment by both the public and private sectors (especially in irrigation), as well as investment in rural infrastructure. He is critical of simple calculations of the value of averted births and suggests that, when population-induced effects are taken into account, "moderate" population growth rates may be more desirable than low rates from a welfare point of view.

Economists concerned with institutional change (e.g., Roumasset, Hayami and Kikuchi) aslo consider the possibility that population growth induces institutional change. Some of this inducement takes the form of scale economies in labor markets. Others (Bardhan and Srinivasan 1971), however, stress the role of a large supply of laborers or potential tenants as a factor that reinforces particular types of contracts and linkages between contracts. These effects may be translated into induced institutional change in the opposite direction.

Actually, the proponents of the Malthusian perspective would acknowledge that many changes do accompany increases in population density. They would point out, however, that such changes do not *enlarge* the technological opportunity set of the economy. They simply cause the utilization of different components of an existing fixed set of technologies. Induced investments in land substitutes, particularly in irrigation capital, may occur under certain forms of organization, but such investment is limited by the low income constraint facing high density societies.

Table 4 summarizes the population-induced effects estimated in Evenson (1982). Population density is estimated to have small negative impacts on research investment, rural electrification and the provision of rural credit. Small positive impacts are estimated for extension and road investments.

The major population-induced structural changes occur on farm size and net cropped area under cultivation. Significant impacts are also realized on irrigation intensities. Note that these population-induced effects are not costless.

These population-induced structural change effects can now be "traced" through the estimates of output supply and factor demand equations.

Table 5 reports these population-induced structure effects in terms of elasticities. It is clear that they are important. An expansion of popu-

TABLE 4

SUMMARY OF POPULATION-INDUCED STRUCTURAL CHANGE

Elasticities of population-density on:	
Research investment	−1.46**
Extension investment	.10
Roads investment	.02
Rural electrification	−.03**
Agricultural credit	−.08**
Farm size	−.24*
Irrigation intensity	−.61**
Net cropped area	−.67**

Source: Tables 2 and 3, Chapter 7.

*Asymptotic "t" 2.0
**Asymptotic "t' 1.5 and 2.0

Elasticities computed at sample means.

TABLE 5

POPULATION INDUCED SHIFTS IN OUTPUT SUPPLY AND FACTOR DEMAND ELASTICITIES OF POPULATION-INDUCED STRUCTURE

Variable	Shift	Variable	Shift
Wheat supply	.531	Fertilizer demand	1.033
Rice supply	1.080	Bullock labor demand	.004
Coarse cereal supply	1.300	Tractor Demand	−.008
Other crop supply	.575	Variable factor demand	.174
Total crop supply	.670		

lation density induces changes in structure that have quite large output effects. A 10 percent expansion in population density induces structural changes that produce a 6.7 percent increase in output. The same changes induce a 1.74 percent change in variable input use. Of course, the changes in structure are not costless. Irrigation, expansion of area cultivated, and research and other public investment require real resources. It appears, however, that the Boserupian perspective on change is supported by the data. These induced effects, however, are not sufficiently large by themselves to prevent production per capita from declining when population expands.

III. Policy Simulations: Population Change, Technology, Land and Irrigation

I now turn to simulations for four policy interventions in India.

1. A 10 percent lower population (and labor force).
2. A 10 percent expansion in technology importation and production.
3. A 10 percent expansion in areas cultivated.
4. A 10 percent expansion in irrigated area.

For the population simulation both a short-run Malthusian and a long-run Boserupian simulation are reported.

The "outcomes" are expressed in terms of real income effects on five population groups:

Rural landless households: less than 1/2 ha.
Small farm households: 1/2 ha. to 5 ha.
Medium farm households: 5 ha. to 15 ha.
Large farm households: greater than 15 ha.
Urban households

For each population group Quizon and Binswanger (1982) obtain consumption weights from the actual survey, so that a change in the consumer price index for each group could be computed. Also, for each group income share data were obtained. Income from labor, bullocks and tractors, land (for those owning land) and nonfarm activities was measured.This enables the computations of nominal income changes. These were deflated by the price change indices to obtain real income changes.

Population growth has three impacts in the basic model. Two of them constitute what I will call the "Malthusian" effects. The first of these is a demand effect. Reducing population growth or the removal of part of the population obviously reduces demand for products. The second is a reduction in the supply of labor to the labor markets. A "short-run" version of these two effects would be realized if India sent a certain proportion of its population abroad (e.g., to the Middle East).

The third effect is what I term "Boserupian" effects. These are population-induced investments in infrastructure and public goods. If these effects are important determinants of agricultural supply, a reduction in population density will also mean a reduction in these induced effects.

I calculated five sets of population effects and report them in Table 6. The first is termed a "Malthusian" calculation. In this simulation it is supposed that, over an extended period, policies are put in place that reduce population *and* labor force growth such that, at the end of the period, both the size of the population and the labor force would be 10 percent lower than in the absence of the policies. The simulation thus takes into account the reduction in demand for products and in the supply of labor.

This first calculation is of considerable interest because it shows that the effects of these policies are large and progressive in terms of their distribution. Real incomes of the population at large rise by 7.77 percent. For the poorest group, the landless laborers, real incomes rise by 14.72 percent, while for the relatively high-income, large farmers, real incomes do not rise appreciably. The 10 percent reduction in labor supply produces a 4.8 percent reduction in agricultural employment and a 12.94 percent increase in real wages. Real land rents (calculated as a residual in this model) actually fall by 25.18 percent. It is the rise in real wage and the decline in returns to landholdings that produce most of the progressiveness in the real income consequences.

The second column shows the simulated Boserupian effects associated with the decline in population. Because population density is lower, population density induced effects (Table 5) are lost. These Boserup effects are also important. When they are considered, the gain in real income for the population as a whole falls by 2.8 percent, so that the net gains are 4.97 percent. The Boserupian effects are themselves progressive in nature, i.e., an increase in population density induces investments that favor the poor. Their loss is thus regressive. In these calculations, their loss reduces the 14.72 percent gain by the land-

TABLE 6

SIMULATED ECONOMIC EFFECTS OF POPULATION GROWTH DECLINE, TECHNOLOGY INVESTMENT, LAND INVESTMENT AND IRRIGATION INVESTMENT, NORTH INDIA

Effect on:	10% Decline in population					10% Increase in		
	Malthusian	Boserupian	Total	Rural landless only	Urban only	Technology base	Land base	Irrigation base
Real Per Capita Income								
(a) All groups	7.77	–2.80	4.97	2.18	.83	.26	2.68	1.78
(b) Rural landless households	14.72	–8.36	6.36	7.68	1.69	1.12	6.64	6.58
(c) Small farm households	11.82	–.59	11.29	3.31	–.15	1.10	–.11	–.38
(d) Medium farm households	6.78	.39	7.17	.73	–1.11	–1.35	–3.19	–4.18
(e) Larger farm households	.69	1.44	2.13	–1.93	–13.45	–3.54	–11.26	–13.52
(f) Urban households	7.86	–1.47	5.59	1.06	10.24	3.36	13.01	12.52
Agricultural Employment	–4.80	–2.95	–7.75	–1.95	–2.29	–.44	–.38	–.07
Real Agricultural Wages	12.94	.38	13.32	7.33	–.66	.22	–1.88	–.10
Real Land Rent	–25.18	40.26	15.08	–5.42	–7.48	–10.20	–31.45	–38.15

less by 8.36 percent, leaving a net gain of 6.36 percent. After adjusting for Boserup effects, however, we still observe that a decline in population has important and progressive effects. The rural landless and small farmers gain most.

I have also simulated two rather specialized population growth effects in columns 4 and 5 in the table. In these I am simply reducing the population of a particular group by 10 percent. (There are no Boserupian effects.) One way to visualize this simulation is to interpret it as a reduction in the population and labor force due to a labor recruitment program for work in Middle Eastern countries. Column 4 shows that if this recruitment were directed at the landless agricultural worker group, these workers would gain more from this specialized effect than from the more general population reduction. (Actually, if only workers were recruited while families were left behind, real wages would rise even more.)

Column 5 shows the effect of recruitment from the urban population only. Here the effect on real incomes is smaller but is probably still progressive. (The calculation assumes that when population is reduced per capita income remains constant.)

For comparative purposes I have also calculated the effects of investments in technology, land expansion and irrigation investment. In these simulations I am not measuring Boserupian effects.These can be looked upon as policy options available as alternatives to population policy. Each option has very different costs, and these costs are not considered in the simulation. For example, a 10 percent increase in the technology base (the HYV-research stock) is much less costly than a 10 percent expansion in the land or irrigation stock (in fact only about one-fortieth as costly).

Interestingly, all three forms of investment have similar effects. They lower food prices, raise real wages and reduce land rents (note that these land rents do not include rents to new land or irrigation; we are presuming public ownership of these rents). Urban consumers benefit most from these programs and large farmers lose most (provided they do not collect newly created rents from the investment).

IV. Concluding Remarks

The relationship between development and fertility is complex. This paper attempted to measure a major part of this relationship and has ignored or set aside another part. It has produced evidence that population growth has important effects not only through the demand for goods and the supply of labor but through the induced structure or "Boserup" effects as well. The simulations reported show these effects to be important. In some sense, one can say that the "Boserup" effect constitutes something of an antidote to the negative and regressive effects of population growth on real income. Our simulations show that real incomes will fall less when "Boserup" effects occur and that the declines will be less regressive as well.

The approach taken in this paper has also attempted to look at the role of non-Boserupian policy effects and has shown that policymakers can invest in technology, land expansion, irrigation, schooling, electrification, etc., and offset the negative effects of population growth if they choose to do so. India has in fact chosen to do so, as have most other countries, and, as a consequence, real incomes have not fallen over the past two decades or so. The simulation model is useful in providing a basis for comparing the costs of alternative policies designed to achieve real income objectives.

I do not have adequate cost data to make a full comparison between the costs of achieving a real income goal through population policies or investments in technology and irrigation. The simulations do make it clear that a given real income objective can be achieved at much lower cost through technology base investment than in land expansion or irrigation investment. It would appear likely that an effective family planning program may achieve these goals at an even lower cost.

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