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Effects of Technical Change in the Iranian Agricultural Sector: A Computable General Equilibrium Analysis

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This study investigates the short-run effects of several types of technical change in the agricultural sector on the economy of Iran. A four-sector computable general equilibrium model is developed to simulate the effects of technical change. Results show that labour-using and capital-saving technical change with an overall increase in productivity appears to be a better option in promoting the self-sufficiency in agricultural commodities. This type of technical change is also shown to increase overall employment in Iran. On the other hand capital-using and labour-saving technical change with no increase in productivity is shown to bring undesired effects to the economy of Iran.

I. Introduction

After the Islamic Revolution of 1979, self-sufficiency in agricultural products has been one of the major objectives of the Iranian government. For various reasons, this objective was not achieved. During 1976-1990, the government of Iran had to increase its cereal imports from 2.076 million metric tones to 6.250 million metric tones (The World Bank (1992)) to meet the domestic demand. This increase in imports implies that a large amount of foreign currency, generated by the oil sector, is expended on consumption goods and thereby limiting the availability of resources for investment. Furthermore, with increasing scarcity of foreign currency, it is difficult for Iran to increase the imports of agricultural products. Therefore, Iran has been focussing on escalating the domestic supply of agricultural commodities to meet its domestic demand.

Agricultural sector is one of the main sectors in the Iranian economy. It accounts for approximately 20% of the national gross domestic product (Iran Statistical Center (1989)) and 24% of the total employed labour force in Iran (Central Bank of the Islamic Republic of Iran (1992)). Theory of production and supply suggests that agricultural output can be increased through a movement along the existing production function by utilizing more of the traditional inputs, and/or a shift to a higher productive production function by employing more advanced technologies. The scope for the increase in output supply through the former approach is limited in Iran due to the shortage of water for irrigation and productive land for agriculture. However, low rates of technical change and public spending on agricultural research and

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extension, and a high rate of illiteracy among farm workers (64%) suggest that there is a large potential to increase agricultural output through technical progress.[1] Changes in technology in one sector, however, involve reallocation and/or displacement of factors of production in other sectors. Furthermore, the rate and nature of technical change may introduce distortions in an economy (Hayami and Ruttan (1985)). This implies that changes in the agricultural sector may have implications for other sectors, and thus, for the overall economy. In this study we attempt to investigate the effects of factor neutral and factor biased technical change in the agricultural sector on the overall economy of Iran.

The empirical estimates of elasticities of factor substitution in the Iranian crop sector over the period 1970-1991 (Salami (1996)) show that capital and labor are substitutes. This suggests that capital using-labor saving and capital saving-labor using technical change have potential to promote growth in agricultural production. Furthermore, there is a potential to extend double cropping program in Iran by increasing the use of capital input in conjunction with the biochemical technological change. The above forms of technical change may have consequences for the agricultural and other producing sectors of Iran.

The effects of technological change have been studied extensively in the context of both developed and developing countries.[2] Coxhead and Warr (1991) and Warr and Coxhead (1993) used computable general equilibrium (CGE) models to examine the consequences of various technological change in agriculture on income distribution in the Philippine economy. Hamilton *et al.* (1988) also employed a CGE model to analyze the growth performance in India, the United States, and the former Soviet Union. Storm (1994) used a CGE model to analyze the macroeconomic impacts of several agricultural policies including input price subsidies in India. However, so far no attempt has been made to investigate the consequences of technical change for the Iranian economy in a general equilibrium framework.[3]

In this paper we developed a short-run computable general equilibrium model and used to investigate the impacts of technical changes in the agricultural sector on the economy of Iran. In this study, cost minimization assumption is made against the profit maximization in studying producers' behavior. This approach is chosen because modeling the effects of technical change is straightforward through the cost minimization approach where the level of output is taken as constant. CGE models have the ability to incorporate inter-sectoral linkages and account for both the direct and indirect impacts of policy shocks on the overall economy. This feature will limit the problems of either overstating or understating the effects of policy shocks on all sectors. The paper is organized as follows. A detailed discussion on modeling technical change is given in Section II. Model specification details and data sources are given in Section III. Simulation results are discussed in Section IV. The final section concludes with a brief summary and conclusions.

1. The annul rate of technical progress in the crop sub-sector, the main sub-sector of agricultural sector, over the period 1970-1991 has been 0.74% (Salami (1996)).
2. See Fulginiti and Perrin (1990), Fan (1991), and Shenggen (1991).
3. Salami (1996) has investigated the issue of determining the nature and direction of technical change in the agricultural sector in a partial equilibrium framework. It should be noted that partial equilibrium analysis does not account for interactions between the agricultural sector the rest of economy.

II. Modeling Technological Change

Factor demand equations are derived by minimizing cost of production subject to a given production technology or output level at time. In this approach, the overall rate of technological change is defined as the rate of reduction in the cost of production over time. Assuming that the cost function $C(Q, P, t)$ defines the minimum cost of producing Q level of output in prevailing input prices P at time t, the overall rate of technical change is, then, given by the following expression (Morrison (1986)):

$$C = \frac{\partial \ln C(\cdot)}{\partial t}. \tag{1}$$

In the presence of technical progress, C is negative indicating the cost reduction as a result of an increase in the factor productivity.

As pointed out by Quizen and Binswanger (1983), the above rate of technical change can be expressed as a share weighted sum of individual factor rates of technical change. That is,

$$C = \sum_{i=1}^{n} s_i \alpha_i, \qquad i = 1, \cdots, n, \tag{2}$$

where s_i denotes the share of input i in total cost of production and α_i is the rate of reduction in the demand for factor i resulting from technical progress when the output level and the factor prices are held constant. That is

$$\alpha_i = \frac{\partial \ln Z_i}{\partial t} \mid_{Q=\bar{Q},\, P_i=\bar{P}_i}, \qquad i = 1, \cdots, n, \tag{3}$$

where Z_i is the demand for the i-th input, Q_i is output level and P_i is input price. From Equation (2) the j-th factor specific technological change, α_j is given by:

$$\alpha_j = \frac{C - \sum_{i}^{n} s_i \alpha_i}{s_j}, \quad \text{where} \quad i \neq j; \quad i, j = 1, \cdots, n. \tag{4}$$

Neutrality and Hicksian biases of technological change are defined in terms of the differential rate of changes in factor productivity, and hence, factor. In the context of a multi-factor production function, Binswanger (1974) defined an index of biased technical change in terms of changes in factor shares. This measure can be presented as:

$$U_i = \frac{\partial \ln S_i}{\partial t}. \tag{5}$$

where $S_i = Z_i P_i / TC$ is the i-th factor share in total cost (TC) of production and U_i denotes the rate of bias. Kohli (1994) shows that the right-hand side of Equation (5) can be decomposed into the factor-specific rate of technical change and the overall rate of technical change.

$$U_i = \frac{\partial \ln Z_i}{\partial t} - \frac{\partial \ln C(\cdot)}{\partial t}. \tag{6}$$

The technical change is i-th factor using, saving, or neutral respectively, if $U_i > 0$, $U_i < 0$, or $U_i = 0$. In other words technological change is factor i using if the demand for this factor falls less rapidly than costs; it is factor i saving if the reverse holds; and technical change is factor neutral if the demand for the factor falls at the same rate as costs.

We use Equations (4) and (6) to simulate five forms of technical change in the Iranian agricultural sector: (i) factor neutral technical change; (ii) technological change that substitutes capital for labor with no change in overall rate of technical progress; (iii) technological change that substitutes capital for labor with an increase in the overall rate of technology; (iv) technological change that substitutes labor for capital with no change in overall rate of technical progress; (v) labor using-capital saving technology accompanied by an increase in the overall rate of technology; and (vi) capital-using land-saving technological change. These forms of technological change may alter factor demand and unit costs in the agricultural sector directly and other sectors indirectly through adjustment in factor and product prices.

In our model C and α_i are used, respectively, in the unit cost and factor demand equations as technological shifters. Selecting the values of C and α_i allows the simulation of the above technical change hypotheses. For example, a 3% increase in rate of factor neutral technical change in agricultural sector requires a shock of negative 3% in the unit cost and factor demand equations in the sector. As well, a 3% progress in labor saving and capital using technological change in the form of factor substitution while leaving land input unchanged can be obtained from the following expression.

$$\alpha_k = \frac{S_e}{S_k} \alpha_e. \tag{7}$$

Equation (7) suggests that a negative shock in the labor demand equation accompanies with a positive shock in the capital demand equation to reflect a labor-saving and capital using technical change.

III. The Model Specification

The economy of Iran is divided into four sectors: agriculture, oil, manufacturing, and services.[4] The first three sectors produce goods to both domestic and foreign markets. The last sector is non-traded in the sense that goods from this sector are consumed completely

4. Since the focus of this study is on changes in the agricultural sector, we have disaggregated the rest of the economy into only three sectors. It should be noted that the GEMPACK computer software which was used later in the study to conduct simulation experiments can handle more than 100 sectors.

within the country. Furthermore, it is assumed that the first and third sectors import commodities from the rest of the world and use them in the production process. Following Armington (1969), domestic and import goods are treated as imperfect substitutes. Both exports and imports are specified as a function of changes in relative prices of domestic and foreign markets. A small country assumption is made in specifying agricultural and manufacturing imports and exports. On the other hand, oil exports are modeled with an assumption that Iran has some market power in the international market. This suggests that Iran faces a downward sloping excess demand for oil from the importers of the rest of world.

The input technology is specified in two levels. At the first level, it is assumed that intermediate inputs and primary factor inputs are demanded in fixed proportions to produce each unit of output. At the second level, substitution is made possible only among primary factor inputs using constant elasticity of substitution technology. The primary factor inputs include labor, capital, and land. It is assumed that labor is used in all sectors and fixed in supply within the country but mobile among sectors. On the other hand capital is assumed to be specific to each sector and fixed in supply. Land is assumed to be used only in the agriculture sector and fixed in supply. International migration of labor and adjustments to the capital stock in response to shocks in the economy are not permitted. These long-run adjustments of labor supply and investment may obscure the short-run impacts of technological changes in the agriculture sector. Furthermore, we model the labor market assuming that wages are rigid. In this specification, the labor market clears through the adjustments in the unemployed labor force. Since capital is sector specific, its rental rates which are endogenous to the model will adjust to clear the markets for capital. The same argument holds for land in the agriculture sector. The complete algebraic model is presented in Appendix 1. The definitions of variables used in the model are given in Appendix 2 while parameters of the model are given in Appendix 3.

The model is short-run in nature. In this scenario, the markets for factor inputs respond to policy shocks through price changes while in the long-run the adjustment is mainly through quantity changes. The model is not closed in the sense that neither the changes in exports equal the changes in imports nor the changes in savings equal the changes in investments. Since capital stock is fixed, there is no change in investment. Consequently, we have assumed no savings. It is assumed that the exchange rate is fixed and balance of payments accommodates any changes in the trade balance.

Following Johansen (1960), the model is specified in the form of proportional rates of change in which variables are specified in a system of linear equations. The main source of data is the Iran input-output table for the year 1986 (Iran Statistical Center (1994)). Matrices of intermediate demand, final demand, primary factor use, taxes and subsidies are presented in Appendix 4. The National Accounts data for the year 1986, published by the Central Bank of the Islamic Republic of Iran, is another source of information used in this study. The data on factor elasticities of substitution used in the agricultural sector are taken from Salami (1996).[5] The values used for other elasticities are drawn from the literature and based on judgement.[6]

5. Data particulars can obtained from the principal author on request.

6. Sadoulet and deJanvry (1991) is the source used for export demand elasticities.

IV. The Simulation Results

Table 1 reports simulation results of various types of technological changes in the Iranian agricultural sector. The values reported are percentage changes in the selected endogenous variables in response to each form of technical change.

Table 1 Effects of Technical Change and Input Subsidies in Agriculture

Variables		NT Change (3%)	K-using, L-saving 0% ↑ in Tech	K-using, L-saving 3% ↑ in Tech	K-saving, L-using 0% ↑ in Tech	K-saving, L-using 3% ↑ in Tech	K-using, D-saving 3% ↑ in Tech
Output Supply	Ag.	2.319	-1.129	2.084	1.046	2.546	2.245
	Oil	0.061	-0.019	0.056	0.021	0.098	0.062
	Manu.	0.413	-0.236	0.376	0.196	0.44	0.401
	Services	-0.12	0.054	-0.108	-0.061	-0.231	-0.124
Output Prices	Ag.	-4.809	2.646	-4.359	-2.273	-5.29	-4.672
	Oil	-0.015	0.005	-0.014	-0.005	-0.025	-0.016
	Manu.	-0.063	0.03	-0.057	-0.03	-0.095	-0.063
	Services	-0.324	0.142	-0.294	-0.156	-0.595	-0.334
Imports	Ag.	-7.285	4.171	-6.621	-3.495	-8.016	-7.085
	Oil	0.053	-0.016	0.049	0.018	0.086	0.054
	Manu.	0.285	-0.175	0.26	0.135	0.247	0.273
Exports	Ag.	64.332	-23.185	56.735	26.128	72.888	61.994
	Oil	0.079	-0.025	0.074	0.027	0.129	0.081
	Manu.	0.778	-0.372	0.704	0.369	1.175	0.78
Household Demand	Ag.	5.052	-2.578	4.558	2.325	5.586	4.901
	Oil	0.0159	-0.005	0.014	0.005	0.025	0.016
	Manu.	0.0638	-0.03	0.057	0.03	0.096	0.063
	Services	0.3259	-0.142	0.294	0.156	0.598	0.335
Labor Demand	Ag.	-1.478	-4.482	-2.419	4.535	3.506	-1.456
	Oil	0.077	-0.024	0.071	0.026	0.124	0.078
	Manu.	1.486	-0.824	1.349	0.7	1.625	1.444
	Services	-0.395	0.18	-0.355	-0.201	-0.757	-0.407
Prices of labor		-0.002	-0.008	-0.004	0.008	0.005	-0.002
Prices of land		-2.937	1.083	-2.791	-0.874	-3.105	-6.857
Price of Capital	Ag.	-2.937	22.531	1.238	-19.88	-7.255	11.025
	Oil	0.254	-0.089	0.235	0.098	0.421	0.26
	Manu.	3.755	-2.057	3.403	1.768	4.119	3.647
	Services	-0.528	0.231	-0.477	-0.259	-1.003	-0.545

Table 1 (Continued)

Variables		NT Change (3%)	K-using, L-saving 0% ↑ in Tech	K-using, L-saving 3% ↑ in Tech	K-saving, L-using 0% ↑ in Tech	K-saving, L-using 3% ↑ in Tech	K-using, D-saving 3% ↑ in Tech
Macro Variables	RGDP	0.869	-0.446	0.786	0.409	1.097	0.855
	Employ	-0.225	-0.883	-0.402	0.857	0.517	-0.236
	Export	1.515	-0.571	1.344	0.628	1.831	1.472
	CPI	-0.611	0.307	-0.553	-0.288	-0.814	-0.604
	Imports	0.125	-0.088	0.115	0.06	0.072	0.117

Note: NT = neutral technical change; Tech = technical change; L = labor, K = capital, and D = land

A. *Neutral Technical Progress in the Agricultural Sector*

Salami (1996) found a 0.74% annual rate of technological progress in one of the Iranian agricultural sub-sectors. This rate of technical progress in the overall agricultural sector may not keep abreast with the growing demand for the agricultural products. A 3% technical progress is thought to be an appropriate rate to meet the growing demand and used in further simulation experiments. The first experiment investigates the effect of a 3% growth rate of factor neutral technical change in the agricultural sector on selected economic variable. Results reported in column 1 of Table 1 show that an increase in technical change, which implies a 3% increase in productivity of all factors of production, would result in a 2.31% rise in agricultural output. An increase in technical change is shown to have a negative impact on factor prices in the agricultural sector and a corresponding depressing effect on output price. The decline in prices of agricultural products as a result of the technical change-induced unit cost reduction strengthens the competitiveness of this sector in the world market. Therefore, we notice 64% increase in the exports of agricultural products. Also, the rise in the sector output reduces the need for importing agricultural commodities by 7.28%.

Neutral technical progress in the agricultural sector also causes a decrease in the cost of production in other sectors. This results in a reduction in the output prices of these sectors and thus a fall in the consumer price index. Since wages are rigid this would cause an increase in the real income of the employed labor force. Also, the fall in the prices of oil and manufacturing sectors causes an increase in the foreign demand for those commodities. Among the macroeconomic variables, we notice an increase in the real GDP which suggests an overall economic growth in Iran. The decrease in consumer price index (0.61%) shows that neutral technological change has a deflationary effect in the economy.

B. *Biased Technical Progress in the Agricultural Sector*

Several different scenarios are simulated to investigate the effects of biased technical change in the agricultural sector. Results of these simulations are reported in columns 2-6 of Table 1. In the first scenario it is assumed that 10% capital input is substituted for labor in the production process leaving the current rate of technical progress in the agricultural sector unchanged. Encouraging producers to use agricultural machinery and equipment for land preparation, threshing, seeding, and on farm transportation can be considered as capital using and labor saving technical change. In the second scenario, it is hypothesized that substitution of capital for labor results in an increase of overall productivity by 3%. Third, a reverse route of technical change is examined where labor is substituted for capital with and without affecting the current level of productivity growth in the agricultural sector. That is, a more labor intensive technical change is developed to use more of the abundant factor input. Finally, a form of capital-using and land-saving technical change is simulated assuming more intensive use of the restrictive factor of production, land. Increase in farm irrigation facilities and agricultural machinery accompanied with the use of high-yielding varieties can be perceived as a form of capital using-land saving technical progress.

Results show that all forms of biased technical change have some similar effects with some differences in their magnitudes. All types of technical change except capital using and labor saving with no technical change result in an increase in the real GDP, a rise in exports and a decline in imports, and cause deflationary effects. They cause an expansion of all trading sectors (oil and manufacturing) and contraction of the non-trading sector (services). We notice a decrease in the demand for labor in the agricultural sector in the face of capital using and labor saving technical change. On the other hand, labor demand is shown to increase in response to capital saving and labor using technical change. The results show that a specific factor using technical change causes an increase in the return for that factor in that sector. In scenario 4-6, we noticed an increase in the demand for labor in oil and manufacturing sector and a decline in the service sector.

Results in column 4 of Table 1 show that the increase in agricultural output in response to labor using-capital saving with 0% increase in the overall technical change is relatively small. This is not surprising because this form of technological change uses more of the abundant factor of production, labor, and less of scarce factor, capital. On the other hand, simulation results (column 2 of Table 1) of technical change that substitutes capital for labor with 0% increase in the overall technical change show a contraction in the agricultural sector as well as in other trading sectors. In the short-run substitution of capital for labor, generates additional demand for capital input which results in a substantial increase (22.53%) in the prices of capital. This, in turn, raises the cost of production, and hence, the price of agricultural product. The increase in output price causes a reduction in foreign demand for Iranian agricultural products directly and the demand for the products of the trading sector indirectly. In addition, the contraction of the trading sectors causes a reduction in real GDP by 0.446%, a decline in aggregate exports by 0.571%. Results reported in column 4 also indicate that capital saving and labor using with no technical change would result the rental rate of capital in agricultural sector decreases approximately by 19.88%.

Simulation results indicated that substituting capital for labor, if it is not accompanied by other types of technological change that increase productivity, will contract the economy and cause inflation. Therefore, it may not be appropriate to device policies which encourage farmers to use more mechanical power. As the supply of agricultural machinery and equipment is scarce relative to labor in Iran, this may not be a viable option to increase the overall rate of productivity in the agricultural sector either. Among different forms of technical progress, the labor-using and capital-saving with an increase in overall technological change is shown to be a better strategy towards self-sufficiency in agricultural products. The elasticity of output supply with respect to this form of technical progress (2.54%) is the highest amongst all. Although this form of technical change may be effective in the short-run, in the long-run the labor-using technology in the agricultural sector may become a restrictive factor for overall growth in the economy. With increasing international mobility of capital and increasing scarcity of productive land resource, in the long-run, the more appropriate form of technical change might be the capital-using and land-saving one.

V. Summary and Conclusion

This study examined the short-run effects of several types of technological change in the Iranian agricultural sector on the national economy. A four-sector computable general equilibrium model is used to achieve this task. Findings of this study are consistent with the well-known wisdom that technological progress is a significant contributor to output increase and a requirement for increasing the competitiveness of the sector in the world market. The nature and the direction of technical progress and the economic environment, however, have important implications for other macroeconomic variables. In Iranian context a labor-using and capital-saving technological change with overall increase in productivity appears to be more appropriate to increase the supply of agricultural output, to ease the shortage of foreign exchange, and to promote employment in rural Iran. This form of technical change expands all trading sectors and increases the demand for labor in the agricultural sector. Since migration of farm workers to the cities and expansion of urban population is unwanted, the labor-using and capital saving technology can also be perceived as a potential strategy for overall economic development in Iran.

Results also show that the capital-using and labor-saving technological change which leaves the overall output growth unchanged brings undesired effects. This form of technical progress causes a reduction in the agricultural sector, declines the employment, dampens the overall economic growth, and hence, the overall welfare of Iranians. This, implicitly, supports the hypothesis of induced technological change that when growing scarcity of capital restricts producers' access to capital inputs, developing and disseminating the technical change that uses more scarce resources is not an appropriate way of increasing agricultural output in the economy.

Appendix 1

Equations of the Model

A. *Final Demand*

(A.1) $\check{z}_{ih}^{d} = C^{h} - P_{ic}$ $\quad i = 1,2,3$

(A.2) $z_{ih}^{d} = C^{h} - P_{ic}$ $\quad i = 4$

(A.3) $\check{z}_{ig}^{d} = C^{g} - P_{ic} + f_{i}^{g}$ $\quad i = 1,2,3$

(A.4) $z_{ig}^{d} = C^{g} - P_{ic} + f_{i}^{g}$ $\quad i = 4$

(A.5) $\check{z}_{iw}^{d} = \gamma_{i}[P_{i} - \$P_{Ei} - \phi]$ $\quad i = 1,2,3$

B. *Demand for Intermediate Inputs*

(B.1) $X_{ij}^{d} = D_{j}^{c}$ $\quad i = 1,2,3,4 \quad j = 1,2,3$

(B.2) $X_{ij}^{d} = z_{j}^{s}$ $\quad i = 1,2,3,4 \quad j = 4$

(B.3) $D_{i}^{c} = \check{z}_{i}^{s} - \sigma_{i}[P_{i} - \theta_{ic}^{d}P_{i} - \theta_{ic}^{m}(\$P_{mi} + \phi)]$ $\quad i = 1,2,3$

(B.4) $M_{i}^{c} = \check{z}_{i}^{s} - \sigma_{i}[(\$P_{mi} + \phi) - \theta_{ic}^{d}P_{i} - \theta_{ic}^{m}(\$P_{mi} + \phi)]$ $\quad i = 1,2,3$

C. *Primary Factor Demands and Markets*

(C.1) $L_{j}^{d} = D_{j}^{c} - \varepsilon_{j}[PL - SL_{j} \cdot PL - SK_{j} \cdot PK_{j} - SA \cdot PA] + \alpha_{lj}$ $\quad j = 1,2,3$

(C.2) $L_{j}^{d} = z_{j}^{s} - \varepsilon_{j}[PL - SL_{j} \cdot PL - SK_{j} \cdot PK_{j}] + \alpha_{lj}$ $\quad j = 4$

(C.3) $\overline{K_{j}}^{d} = D_{j}^{c} - \varepsilon_{j}[PK - SL_{j} \cdot PL - SK_{j} \cdot PK_{j} - SA \cdot PA] + \alpha_{kj}$ $\quad j = 1,2,3$

(C.4) $\overline{K_{j}}^{d} = z_{j}^{s} - \varepsilon_{j}[PK - SL_{j} \cdot PL - SK_{j} \cdot PK_{j}] + \alpha_{kj}$ $\quad j = 4$

(C.5) $\overline{A_{j}}^{d} = D_{j}^{c} - \varepsilon_{j}[PA - SL_{j} \cdot PL - SK_{j} \cdot PK_{j} - SA \cdot PA] + \alpha_{aj}$ $\quad j = 1$

(C.6) $EL = \sum_{j=1}^{4} SE_{j} \cdot L_{j}^{d}$

(C.7) $PL = (1/\lambda) \cdot EL$

(C.8) $\overline{E} = \phi_{u} \cdot UL + \phi_{e} \cdot EL$

D. *Market Clearing Conditions*

(D.1) $P_{j} = \sum_{j=1}^{4} W_{ij}P_{ic} + V_{lj}PL_{j} + V_{kj}PK_{j} + V_{aj}PA_{j} + \phi_{tj}\tau_{aj} + \phi_{qj}Q_{j} - C$ $\quad i = 1,2,3 \quad j = 1,2,3,4$

(D.2) $P_{ic} = \theta_{ic}^{d}P_{i} + \theta_{ic}^{m}[\$P_{mi} + \theta]$ $\quad i = 1,2,3$

(D.3) $P_{ic} = \sum_{j=1}^{4} W_{ij}P_{ic} + V_{lj}PL_{j} + V_{kj}PK_{j} + V_{aj}PA_{j} + \phi_{tj}\tau_{aj} + \phi_{qj}Q_{j} - C$ $\quad i = 4 \quad j = 1,2,3,4$

(D.4) $Z_i^s = \beta_{ik} Z_{ik}^d + \beta_{iq} Z_{iq}^d + \beta_{ixc} Z_{ixc}^d + \sum_{j=1}^{4} \beta_{ix} X_{ij}^d \quad i = 1,2,3 \quad j = 1,2,3,4$

(D.5) $Z_i^d = \theta_{ic}^d D_i^c + \theta_{ic}^m M_i^c \quad i = 1,2,3$

(D.6) $Z_i^s = \beta_{ik} Z_{ik}^d + \beta_{iq} Z_{iq}^d + \sum_{j=1}^{4} \beta_{ix} X_{ij}^d \quad i = 4 \quad j = 1,2,3,4$

E. *Exports*

(E.1) $E = \sum_{j=1}^{3} \xi_{iE} [Z_{ixc}^d + \$ P_{Ei} + \phi]$

F. *Household Income and Expenditure*

(F.1) $Y^h = \sum_{j=1}^{4} \mu_{lj} (PL + L_j^d) + \sum_{j=1}^{4} \mu_{kj} (PK + \overline{K}_j) + \sum_{j=1}^{4} \mu_{aj} (PA + \overline{A}_j)$

(F.2) $C^h = APC^h + Y^h - \tau^h$

(F.3) $RC^h = C^h - CPI$

G. *Government Income and Expenditure*

(G.1) $Y^g = \sum_{j=1}^{4} \omega_{qj} (Q_j + \sum_{j=1}^{4} X_{ij}) + \sum_{j=1}^{3} \omega_{cd} (P_i + D_i^c + \tau_{cd}) + \omega_c (APS^h + Y^h)$

$\sum_{i=4}^{4} \omega_{oi} (P_{ic} + Z_i^s + \tau_{oi}) + \omega_h (\tau^h + Y^h)$

(G.2) $C^g = APC^g + Y^g$

(G.3) $RC^g = C^g - CPI$

H. *Real GDP*

(H.1) $RGDP = Y^h - CPI$

I. *Price Index*

(I.1) $CPI = \sum_{j=1}^{4} H_j P_{ic}$

Appendix 2

Variables of the Model

Variable	Definition
C^h	Aggregate household expenditure
C^g	Aggregate government expenditure
RC^h	Real household expenditure
RC^g	Real government expenditure
$RGDP$	Real GDP
E	Total Exports Value
UL	Unemployed labour force
M	Total Imports Value
P_{ic}	Price of composite commodities
PL	Price of labor
PK_j	Rental price of capital in industry
PA	Rental price of land
P_i	Price of domestic good i
$\mathcal{Z}^d_{ih}$	Demand for composite commodities by households
Z^d_{ih}	Demand for services by households
$\mathcal{Z}^d_{ig}$	Demand for composite commodities by government
Z^d_{ig}	Demand for services by government
X^d_{ij}	Demand for intermediate input j by industry i
$\mathcal{Z}^S_i$	Supply of output of by industry i
Z^S_i	Supply of services
$\mathcal{Z}^d_i$	Demand for output of composite commodities i
$\mathcal{Z}^d_{iw}$	Foreign demand for commodity i
D^c_i	Usage of domestic goods in composite goods i
M^c_i	Usage of imported goods in composite goods i
L^d_i	Demand for labor by industry i
Y^h	Household income

Variable	Definition
Y^g	Government income net of subsidies
Φ	Exchange rate - local dollars per foreign dollar
CPI	Consumer price index
α_{lj}	Labour-specific technical change
α_{kj}	Capital-specific technical change
α_{Aj}	Land-specific technical change
C	Cost shifter technical change in agricultural sector
A^g_j	Exogenous shifter in government expenditure
$\overline{E}$	Total labour force
EL	Employed labour force
$\$P_{mj}$	Import prices in foreign currency
$\$P_{Ej}$	Export prices in foreign currency
APC^h	Average propensity to spend by households
APS^h	Average propensity save by households to save
APC^g	Average propensity to spend by government
Ω_j	Rate of subsidy on intermediate input in industry j
τ_{Qj}	Tax rate on revenue of industry j
τ^h	Tax rate on household income
K^d_j	Demand for capital by industry j
A^d_j	Demand for land by agricultural sector

Appendix 3

Coefficients of the Model

γ_i	Elasticity of demand for exportable goods
σ_i	Elasticity of substitution between domestic and imported goods
λ	Supply elasticity of labour input
ε_j	Elasticity of substitution between primary factors in industry i
SL_i	Share of labor in total factor inputs in i
SK_i	Share of capital in total factor inputs in industry i
SA	Share of land in total factor inputs in agriculture
θ^{d}_{ic}	Share of domestic good i in the composite good
θ^{m}_{ic}	Share of imported good i in the composite good
TC_i	Total costs in industry i excluding tax
W_{ji}	Share of good j in costs of industry i
V_{jl}	Share of labor in costs of industry i
V_{ki}	Share of capital in costs of industry i
V_{aj}	Share of land in costs of industry i
β_{ih}	Share of households demand in total demand for good i
β_{ig}	Share of government demand in total demand for good i
β_{ir}	Share of intermediate usage in total demand for good i
β_{iw}	Share of foreign demand in total demand for good i
ϕ_{ti}	Share of production tax in total demand for good i
ϕ_{si}	Share of subsidy in total demand for good i
O_i	Share of output of each sector in total output
H_i	Share of good i in total household expenditure
ξ_{im}	Share of imported good i in total value of imports
ξ_{iE}	Share of exportable good i in total value of exports
μ_{lj}	Share of wages in gross household income in industry i
μ_{kj}	Share of rent on capital in gross household income in industry i
μ_{Aj}	Share of rent on land in gross household income in industry i
ω_{ti}	Share of production taxes on revenue of industry i in government income
ω_{si}	Share of subsidies on intermediate inputs of industry i in government income
ω_{hi}	Share of households income taxes in government income
ω_{p}	Savings from households as share of government income
SE_i	Share of sector j in total employed labour force
ϕ_e	Share of total employed labour force in the economy
ϕ_u	Share of total unemployed labour force in the economy

Appendix 4

Data used in the model

Matrix of intermediate inputs (derived from Iran input-output table 1986)

Sector	Agri.	Oil	Manu.	Serv.
Agri.	681879	333	1705077	44747
Oil	6395	316	109092	29717
Manu.	347706	18525	1735950	2361220
Serv.	311733	46842	680105	1355092

Matrix of final demand (derived from Iran input-output table 1986)

Sector	HH. demand	Gov. demand	Exports	Imports
Agri.	867954	104305	12893	-32890
Oil	490	0	459971	-2006
Manu.	3787081	422118	203063	-1582740
Serv.	5784597	5173129	0	0

Matrix of primary factor use, taxes and subsidies (derived from Iran input-output table 1986)

Sector	Agri.	Oil	Manu.	Serv.
Cap	278676	52757	2130288	6548841
Land	890858	0	0	0
Labor	912000	202258	916858	2872508
Tax	1	382875	163664	264110
Subsidies	-593	-6019	-125392	-46862

References

Antle, J.M., and A.S. Aitah (1983), "Rice Technology, Farmer Rationality, and Agricultural Policy in Egypt," *American Journal of Agricultural Economics*, 65, 667-674.

Armington, P.A. (1969), *Theory of Demand for Products Distinguished by Place of Production*, International Monetary Fund Staff Papers, 16, 179-201.

Binswanger, H.P. (1974), "The Measurement of Technical Biases with Many Factors of Production," *American Economic Review*, 64, 964-976.

Central Bank of the Islamic Republic of Iran (1992), *National Accounts of Iran 198-1990*.

Coxhead, I.A., and P.G. Warr (1991), "Technical Change, Land Quality, and Income Distribution: A General Equilibrium Analysis," *American Journal of Agricultural Economics*, 73, 345-360.

Dixon, P., B. Parmenter, A.A. Powell, and P.J. Wilcoxen (1992), *Notes and Problems in Applied General Equilibrium Economics*, Amsterdam: North-Holland Publishing Company.

Dixon, P., B. Parmenter, J. Sutton, and D. Vincent (1982), *ORANI: A Multi-Sectoral Model of the Australian Economy*, Amsterdam: North-Holland Publishing Company.

Fan, S. (1991), "Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture," *American Journal of Agricultural Economics*, 73, 66-274.

Fulginiti, L.E., and R.K. Perrin (1990), "Argentine Agricultural Policy in a Multiple-Input, Multiple-Input Framework," *American Journal of Agricultural Economics*, 72, 279-86.

Hamilton, B., S. Mohammad, and J. Whalley (1988), "Applied General Equilibrium Analysis and Perspective on Growth Performance," *Journal of Policy Modeling*, 10, 281-297.

Hayami, Y., and V.W. Ruttan (1985), *Agricultural Development*, Baltimore, Johns Hopkins University Press.

Hertel, T.W., J.M. Horridge, and K.R. Pearson (1992), "Mending the Family Tree: A Reconciliation of the Linearization and Levels Schools of AGE Modeling," *Economic Modeling*, October, 385-407.

Iran Statistical Center (1989), *Statistical Yearbook of Iran*, Plan and Budget Organization, Tehran.

_____ (1994), *Input-Output Table of Iran Economy 1986*, Plan and Budget Organization, Tehran.

Johansen, L. (1960), *A Multi-Sectoral Study of Economic Growth*, Amsterdam: North-Holland Publishing Company.

Kohli, U. (1994), "Technological Biases in U.S. Aggregate Production," *The Journal of Productivity Analysis*, 5, 5-22.

Kuroda, Y. (1988), "The Output Bias of Technological Change in Postwar Japanese Agriculture," *American Journal of Agricultural Economics*, 70, 663-673.

Morrison, C.J. (1992), "Unravelling the Productivity Growth Slowdown in the United States, Canada, and Japan: The Effects of Sub-Equilibrium, Scale Economies and Markups," *The Review of Economics and Statistics*, 74, 381-393.

Quizon, B.J., and H.P. Binswanger (1983), "Income Distribution in Agriculture: A Unified Approach," *American Journal of Agricultural Economics*, 65, 526-538.

Sadouleth, E., and D. DeJanvry (1991), "Agricultural Trade Liberalization for the Low Income Countries: A General Equilibrium-Multi Market Approach," *Working Paper No. 614.*

Salami, H. (1996), “Production Structure and Productivity Measurement in the Iranian Crop Sector,” Unpublished Ph.D. Thesis, University of Alberta, Canada.

Shenggen, F. (1991), “Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture,” *American Journal of Agricultural Economics*, 72, 265-275.

Storm, S. (1994), “The Macroeconomic Impact of Agricultural Policy: A CGE Analysis for India,” *Journal of Policy Modeling*, 16, 55-95.

Warr P.G., and I.A. Coxhead (1993), “The Distributional Impacts of Technical Change in Philippine Agriculture: A General Equilibrium Analysis,” *Food Research Institute Studies*, 22, 253-274.

World Bank (1992), *World Development Report 1992, Development and the Environment*, New York, Oxford University Press.

Young, D.L., R.C. Mittelhammer, A. Rostamizadeh, and D.W. Holland (1987), *Duality Theory and Applied Production Economics Research: A Pedagogical Treatise*, Cooperative Extension, College of Agriculture and Home Economics, Washington State University.