OUTLINE OF AN ECONOMETRIC MODEL

FOR CHINESE ECONOMIC PLANNING

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1. INTRODUCTION

The basic allocative problems facing the economic planners of the People's Republic of China are to determine what fractions of total national output are to be devoted to current consumption and investment, how total investment is to be distributed among different industries, and how much each industry is to produce in order to satisfy the needs of consumption and investment. These allocative problems can be solved by considering the productive capabilities of the economy and the preferences of the society for different categories of consumption goods and for present consumption as compared with future consumptions. An econometric model is an aid to economic planning as it describes quantitatively the production possibilities available and how different government decisions will affect the production and consumption of various commodities through time.

In the econometric model to be outlined in this paper, the production possibilities are described by a dynamic input-output table. For the production of each industry, the corresponding column of the table shows the input requirements from all industries, and the requirements of labor and capital goods. Services from skilled labor and the stocks of capital goods in different industries are considered to be the limiting factors which restrict the quantities of final outputs. In any one year, the society has the option to allocate its final outputs for current consumption or for capital accumulation. The latter use will help increase the quantities of final outputs available in the future. The first part of our model, to be presented in Section 2, consists of a set of dynamic input-output relations, showing how the curtailment of current consumption can help augment the capital stocks for future production.

Besides describing the production possibilities, our model needs to explain how final outputs in different industries are determined. Basically, these products can be used for private consumption, public and government consumption, defense, investment, and exports. The second part of our model, to be presented in Section 3, consists of a set of equations explaining the components of final demand for the products. Some components of final demand are treated as control variables. Once the values of these control variables are given, the final demand equations and the production constraints given by the dynamic input-output relations will determine the outputs of different industries and their uses through time. Thus the time paths of all output, consumption, and capital stock variables can be determined by the first two parts of our model. Some important uses of these two parts of the model will be discussed in Section 3.

To insure that the consumption goods produced according to the first two parts of our model will be appropriately distributed to the consumers in rural and urban areas, the government exercises control over the total incomes of the rural and urban populations (by setting purchase prices and purchase quotas for farm products, and setting the wage rates for workers), over the quantities of certain commodities to be consumed (by rationing), and over the prices of a large number of products. The third part of our model, to be presented in Section 4, is concerned with the determination of income and prices. Currently the government of the People's Republic of China is considering economic reforms, partly to allow the forces of the markets to function properly. We will indicate how part 3 of our model should be changed when these reforms are introduced.

The fourth and last part of our model deals with government revenues and expenditures. Not only is there a problem to insure that the consumption goods produced get distributed appropriately to the rural and urban consumers, as we discuss in part 3; there is also a problem for the government planners to balance

the purchasing power available for private consumption, government consumption, defense, and investment. If prices of all consumer goods were fixed, then increasing the wage rates and the purchase prices of farm products would raise the incomes of urban workers and farmers, and thus tend to increase the quantities of goods demanded by private consumers. As the government increases urban wages and the purchase prices of farm products, provided that its budget is balanced, it will have less to spend on government consumption, defense, and investment. While the distribution of resources for different uses can be planned in physical terms according to parts 1 and 2 of our model, financial flows through the government budget serve to control the flows of physical resources.

Our model can help solve the allocative problems first posed in this paper. If the time paths of the important production, consumption and price variables are charted by the model, given the time paths of the policy variables, the policy makers will know the options available. Such knowledge would help them decide which options to choose. In addition, we will indicate how optimal control techniques can be used for the selection of good policies. If one is willing to assign weights to the target variables in an objective function, including consumption, defense, inflation, etc., one can apply the method of optimal control to find the best production and investment policies to achieve these objectives. A flexible way to use optimal control methods is to vary the weights in the objective function to trace out the highest consumption levels achievable given any defense requirements and the condition of price stability. Such control experiments will provide a more efficient way to obtain the options available to the government decision makers, and the optimal policies associated with these options.

2. A DYNAMIC INPUT-OUTPUT MODEL

One way to describe the production possibilities existing in the Chinese economy is by a dynamic input-output table in physical units. To facilitate discussion, we can refer to the static input-output table in 1952 prices constructed by Haruki Niwa (1969) for the Chinese economy in 1956. This table includes 22 sectors. The gross output and the components of final demand for each industry, in billions of 1952 yuan, are given in Table 1. Besides the 22 industries listed, we need an education industry which produces skilled labor. Note that our model would require an input-output table in physical units, whereas Table 1 contains data in 1952 values.

Let z_t be a column vector of 23 elements denoting the gross outputs of these productive activities at time t, A be an input-output matrix whose j-th column denotes the inputs of the 23 products used in producing one unit of the j-th output, and y_t be a column vector denoting the final outputs. We have the familiar relation between the final outputs and gross outputs:

$$z_t = Az_t + y_t \qquad (2.1)$$

In addition to the intermediate products from the 23 industries, the production of each product may require using the stocks of two capital goods, machinery and construction, and skilled labor to be denoted by s_{1t}, s_{2t}, and s_{3t} respectively. Let B be a 3×23 matrix with each column specifying the input requirements from the stocks of two capital goods and skilled labor, to be denoted by the vector s_t. These resource requirements are given by

$$Bz_t \leq s_{t-1} \qquad (2.2)$$

The vector s_{t-1} of capital stocks at the end of year t-1 is given for the production in each year t but s_t will be affected by investment I_t in year t:

TABLE 1

1956 Output of PRC (billions of 1952 yuan)[*]

	z	Az	y	C	G	I	INV	D	EX	IM
(1) Agriculture-food	39.9	13.0	26.8	26.4	.0	.0	-.1		.5	
(2) Agriculture-textile material	3.5	2.4	1.1	.0	.0	.9			.8	.6
(3) Forestry	2.8	1.0	1.8	1.8	.0					
(4) Coal & allied prod.	1.9	1.2	.7	.5	.1		.1			
(5) Petroleum	1.7	2.9	-1.2	.0	.1					1.3
(6) Iron ore	.6	.6	.0	.0	.0					
(7) Non-ferrous metal	3.1	2.6	.5	.0	.0				.5	
(8) Processed food	13.7	3.1	10.5	8.2	.0			.1	2.4	.1
(9) Textiles	17.5	8.8	8.7	8.2	.0			.1	.5	.2
(10) Construction materials	4.2	4.6	-.4	.2	.0		-.7		.1	
(11) Chemicals	5.6	5.4	.2	.4	.0				.6	.9
(12) Iron and steel	9.8	10.0	-.2	.0	.0			.1	.2	.5
(13) Metal working	4.0	3.5	.5	.5	.0	.2		.1		.2
(14) Machinery	8.9	2.5	6.3	.6	.0	4.7		3.0		2.0
(15) Other producer goods	3.1	2.5	.5	.2	.0				.5	.3
(16) Industrial con- sumer goods	5.9	3.9	2.0	1.8	.0				.3	.3
(17) Gas	.1	.0	.1	.1	.0					
(18) Electric power	.9	.8	.1	.1	.0					
(19) Transportation and communications	9.5	4.7	4.8	4.1	.2	.1		.3	.9	.8
(20) Construction	15.3	1.4	13.9	.0	.0	13.8		.1		
(21) Services	23.0	6.5	16.5	14.3	.8	1.2		.1	.3	.3
(22) Not classified	10.3	9.3	1.0	1.1	1.4		-1.5	.1	.5	.5
Gross input	185.3	91.0	94.3	68.7	2.8	20.9	-2.3	3.9	8.2	8.0

[*]Source: Haruki Niwa (1969), Table 1.

$$s_t = I_t + (I-\delta)s_{t-1} \tag{2.3}$$

where δ is a diagonal matrix indicating the rates of depreciation of capital goods and human capital.

Let c be a row vector of requirements of unskilled labor in the production of the one unit of output in the 23 industries. The total demand for unskilled labor in producing gross output z_t is therefore cz_t. We assume for China that capital stocks and skilled labor but not unskilled labor are the limiting factors. Land itself is not treated here as a limiting factor for the production of agricultural products because the same piece of land can be made much more productive by suitable capital investments. From (2.1) and (2.2), it follows that the combination of net outputs y_t that can be produced by the available capital stocks s_{t-1} is given by

$$B(I-A)^{-1}y_t \leq s_{t-1} \tag{2.4}$$

Given any y_t, the total demand for unskilled labor is

$$cz_t = c(I-A)^{-1}y_t \tag{2.5}$$

Once we can obtain projections of population and labor force, the difference between labor supply and labor demand given by (2.5) provides an estimate of unemployment which will require the attention of the government economic planners.

Of the 22 products listed in Table 1, numbers 14 (machinery) and 20 (construction) are the two capital goods which, together with skilled labor, limit the productive capabilities of the economy. Numbers 6, 7, 10 and 12 are intermediate products. The outputs of these products constitute neither investment goods nor consumption goods, but the final demands may be positive if they are exported. The remaining 16 products are all consumption goods, except number 2,

which, according to the table, mainly goes to investment. We will treat it as a consumer good when we come to explain the demand for final products in the next section because we do not consider the stock of this product as a limiting factor in the Chinese economy. Otherwise, s_t in equations (2.2), (2.3) and (2.4) would be a vector consisting of four elements instead of three.

Let the vector y_t, including the production of skilled labor, be composed of subvectors y_t^c (16 consumption goods), y_t^m (4 intermediate products) and y_t^i (3 investment goods, including investment in human capital). Accordingly, re-write equation (2.4) as

$$B(I-A)^{-1}y_t = B_1y_t^c + B_2y_t^m + B_3y_t^i = s_{t-1} \qquad (2.6)$$

Assuming B_3 to be nonsingular, we can use (2.6) to determine the vector y_t^i of investment goods as a linear function of s_{t-1}, y_t^c and y_t^m,

$$y_t^i = B_3^{-1}s_{t-1} - B_3^{-1}B_1y_t^c - B_3^{-1}B_2y_t^m \qquad (2.7)$$

(2.7) shows that, given the productive capabilities provided by the initial stock s_{t-1}, the more the resources are used to produce consumption goods y_t^c, the less will be available for the production of investment goods y_t^i. Investment goods will go either to I_t to increase the productive capacity of the economy or to the remaining uses which include defense and exports. If the government can decide on the quantities of consumption goods y_t^c to produce, the quantities of intermediate products y_t^m for net exports, and the quantities of investment goods used for defense and for exports, equation (2.7) will determine y_t^i and hence I_t, given s_{t-1}. Equation (2.3) will determine s_t. The dynamic evolution of the input-output model will thus be determined. It is to the explanation of y_t^c, y_t^m and the other uses of investment goods that we will turn in the next section.

3. FINAL DEMAND FOR PRODUCTS

The government of a centrally planned economy can decide on the quantities of different consumption goods to produce, realizing that increasing the production of consumption goods y_t^c will mean the reduction of investment goods y_t^i at the rates given by the matrix $B_3^{-1}B_1$ in equation (2.7). In its decision on y_t^c, the government will consider the relative needs for the different consumer goods. Its perception of such needs may coincide, to various degrees, with the needs as expressed by the consumers themselves through their demand behavior. Our model will express these needs mathematically no matter whether they are based on the government's own perception or the demand behavior of the consumers.

According to Table 1, each consumption good in y_t^c can be used for private consumption C, government consumption G, inventory accumulation INV, defense D or exports EX, while imports IM supplement the domestic production. We consider first the determination of the vector C for private consumption. Given the relative prices p_i of consumer goods, the expenditures $p_i C_i$ on them are approximated by linear functions of total consumption expenditures $\sum_j p_j C_j$,

$$p_i C_i = a_i (\sum_j p_j C_j) + b_i \qquad (3.1)$$

where $\sum_i a_i = 1$ and $\sum_i b_i = 0$. Such an expenditure system is only an approximation. These demand functions are not homogeneous of degree zero in prices unless b_i/p_i is. The constants b_i will be affected by the choice of units for p_i. Therefore, we assume a fixed numeraire consumer good for which the price is unity in order that the approximation (3.1) will be more accurate. The entire system of demand equations for m consumption goods can be written as

$$\begin{bmatrix} (1-a_1)p_1 & -a_1p_2 & \cdots & -a_1p_m \\ -a_2p_1 & (1-a_2)p_2 & \cdots & -a_2p_m \\ & & \ddots & \\ -a_mp_1 & -a_mp_2 & \cdots & (1-a_m)p_m \end{bmatrix} \begin{bmatrix} C_1 \\ C_2 \\ \vdots \\ C_m \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_m \end{bmatrix} \qquad (3.2)$$

The matrix on the left of (3.2) has rank m-1, since the sum of the m rows is a zero vector. If we let the first good be the numeraire good, for which $p_1=1$, the demands for all other goods can be expressed as a function of C_1 according to (3.2):

$$\begin{bmatrix} (1-a_2)p_2 & \cdots & -a_2p_m \\ & \ddots & \\ -a_mp_2 & \cdots & (1-a_m)p_m \end{bmatrix} \begin{bmatrix} C_2 \\ \vdots \\ C_m \end{bmatrix} = \begin{bmatrix} b_2 \\ \vdots \\ b_m \end{bmatrix} + \begin{bmatrix} a_2 \\ \vdots \\ a_m \end{bmatrix} C_1 \qquad (3.3)$$

C_1 can be used as a control variable in the model. Given C_1 the demand for the remaining consumer goods will be determined by (3.3).

To reflect the Chinese reality, it will be necessary to study the consumption patterns of the rural and urban populations separately. To do so, we simply decompose the vector C into its rural and urban components C^r and C^u. Each component will be explained by equations of the form (3.1) to (3.3), with superscripts r and u added to the parameters p_i, a_i and b_i. Both C_1^r and C_1^u will become control variables for the determination of the demands for the remaining consumer goods C_i^r and C_i^u (i=2,...,m) in the rural and urban areas.

Linear schemes of the same form can be used to determine the vectors G and D of government demand and defense demand respectively, the latter including both consumption goods and investment goods, as indicated in Table 1. As a result, the vectors C^r, C^u, G and D can be expressed, respectively, as linear functions

of the scalars C_1^r, C_1^u, G_1 and D_k, where D_k may be the defense use of machinery, for example. The vector IM of imports is assumed to be a linear function of the vector y_t of final outputs. So is the vector of planned inventory changes INV. The vector EX of exports is treated as exogenous to our model as it can be explained by a set of exports equations supplementary to our model; or some elements of it can be treated as control variables.

These assumptions permit us to write the vector y_t of final outputs as

$$
y_t = \begin{bmatrix} y_t^c \\ y_t^m \\ y_t^i \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ I_t \end{bmatrix} + \begin{bmatrix} C_t^r \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} C_t^u \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} G_t \\ 0 \\ 0 \end{bmatrix} + D_t + INV_t - IM_t + EX_t
$$

$$
= \begin{bmatrix} 0 \\ 0 \\ I_t \end{bmatrix} + \Gamma_1 x_t + \Gamma_2 y_t + EX_t + \gamma_0 \tag{3.4}
$$

where x_t denotes a vector of the four control variables C_1^r, C_1^u, G_1 and D_k which determine the demands C_t^r, C_t^u, G_t and D_t; Γ_2 is a matrix derived from the linear functions explaining planned inventory changes INV_t and imports IM_t; and γ_0 is a vector of constants collected from the above linear functions. Solving (3.4) for y_t, we obtain

$$
y_t = (I-\Gamma_2)^{-1}(\begin{bmatrix} 0 \\ 0 \\ I_t \end{bmatrix} + \Gamma_1 x_t + EX_t + \gamma_0)
$$

$$
= \Gamma_3 I_t + \Gamma_4 x_t + \Gamma_5 EX_t + \beta \tag{3.5}
$$

The three components of y_t according to (3.5) can be written as

$$
\begin{bmatrix} y_t^c \\ y_t^m \\ y_t^i \end{bmatrix} = \begin{bmatrix} \Gamma_{31} \\ \Gamma_{32} \\ \Gamma_{33} \end{bmatrix} I_t + \begin{bmatrix} \Gamma_{41} \\ \Gamma_{42} \\ \Gamma_{43} \end{bmatrix} x_t + \begin{bmatrix} \Gamma_{51} \\ \Gamma_{52} \\ \Gamma_{53} \end{bmatrix} EX_t + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} \qquad (3.6)
$$

The last equation of (3.6) can be solved for I_t,

$$
I_t = \Gamma_{33}^{-1} y_t^i - \Gamma_{33}^{-1} \Gamma_{43} x_t - \Gamma_{33}^{-1} \Gamma_{53} EX_t - \Gamma_{33}^{-1} \beta_3 \qquad (3.7)
$$

When the right-hand side of (2.7) is substituted for y_t^i in (3.7), I_t becomes a linear function of y_t^c, y_t^m, s_{t-1}, x_t and EX_t. When this linear function is substituted for I_t in the first two equations of (3.6), and the result is solved for y_t^c and y_t^m, we obtain

$$
\begin{bmatrix} y_t^c \\ y_t^m \end{bmatrix} = \alpha_1 s_{t-1} + \alpha_2 x_t + \alpha_3 EX_t + \alpha_0 \qquad (3.8)
$$

Equations (3.8) and (2.7) imply that y_t^i is also a linear function of s_{t-1}, x_t and EX_t. If y_t^i in (3.7) is replaced by this function, I_t also becomes a linear function of s_{t-1}, x_t and EX_t. By equation (2.3), s_t is a linear function of the same variables. These equations can be summarized by writing

$$
\begin{bmatrix} y_t \\ I_t \\ s_t \end{bmatrix} = \begin{bmatrix} 0 & 0 & A_{13} \\ 0 & 0 & A_{23} \\ 0 & 0 & A_{33} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ I_{t-1} \\ s_{t-1} \end{bmatrix} + Cx_t + BEX_t + b \qquad (3.9)
$$

in the notation of Chow (1975). Equation (3.9) explains how the state variables y_t, I_t and s_t evolve through time, given the time paths of the control variables x_t and the exogenous variables EX_t. Thus the government planners need only to fix the four control variables C_1^r, C_1^u, G_1 and D_k in x_t and predict or plan the demand for exports exogenously. The productions, investments and capital stocks

of the economy will be completely determined through time by the linear dynamic model (3.9).

There are several important uses of the model constructed so far. By keeping the time paths of the four components of demand C_{1t}^r, C_{1t}^u, G_{1t} and D_{kt} of the rural population, urban population, government consumption, and defense at a tolerable minimum, a government planner can use the model (3.9) to find out the time paths of investments I_t and capital stocks s_t that can be generated, subject to the constraints of the productive capacities of the economy and to the relative needs of the four major users for the different products. Such an exercise would help avoid planning a great leap forward that is economically not feasible. By raising the consumption paths C_{1t}^r and C_{1t}^u and observing the resulting decreases in the paths of investments I_t and capital stocks s_t, the planner can observe the trade-off relationships between consumption and capital formulation and will be in a better position to decide on the fractions of total output to be allocated to consumption as compared with investment. Similarly, by raising the path D_{kt} of production for defense and observing the resulting changes in I_t and s_t, one is better able to decide on the allocation of resources for these uses. In the last section of this paper, we will point out how optimal control techniques can be applied to trace out such trade-off relationships more efficiently, and how to find out the quantities of consumption goods C_{1t}^r and C_{1t}^u which have to be sacrificed for hypothetical increases in defense expenditures, subject to the condition that the accumulation of capital stock should remain the same.

The byproducts of these calculations are the output vectors y_t. Given y_t and the input-output relation (2.1), one can calculate the gross outputs z_t to be produced by different sectors. Using the matrices B and c in (2.2) and (2.5) respectively, one can also estimate the quantities of capital stock and investment to be allocated to each industry and the quantity of unskilled labor each

industry will absorb. In sum, such a model can be used to answer the important questions often raised by the Chinese economic planners: what are the right proportions between consumption and investment, between agricultural output and industrial output, between outputs of heavy industry and light industry, and between investments in agriculture, light industry and heavy industry? How much labor can each industry absorb during a planning period and how much unemployment will be generated, given exogenous projections of the growths of population and the labor force?

While such a model is very useful in answering the above broad questions concerning the productive capabilities of an economy, it says nothing about how the planned production levels can actually be achieved—how to get the farmers, workers, and the managers to cooperate to produce the outputs which the economy is capable of producing. Furthermore, assuming that the outputs are actually produced according to plan, we need to know how they are appropriately distributed to the rural and urban consumers and to the government users. This topic will be discussed in the next two sections.

4. INCOME AND PRICES

There are two ways by which the government of PRC controls the distribution of outputs to the rural and urban populations. One is by controlling the incomes of these populations. Since the government fixes the prices of most commodities in China, it should not distribute much more incomes to the rural and urban populations than the total values of the consumer products available to them at these prices. Otherwise, shortages and/or inflation will result. The second way is by rationing. In China, urban housing, grain, vegetable oil, meat, sugar, cotton cloth are rationed, among other commodities. We will first examine how rural and

urban incomes are determined, and then try to explain the determination of prices.

The government exercises control over rural income mainly by setting the compulsory quota and the price of the output which it purchases from the farmers, and by a tax on agricultural output which was recently 9 percent for grain and 5 percent for other agricultural products. Let

q_{it} = government purchase quota of agricultural product i, iεA,

 A being a set of agricultural products,

p_{it}^* = government purchase price of product i,

p_{it}^r = market price of product i in rural areas,

θ = fraction of agricultural income used for working capital, equipment

 and welfare fund, and

t_i = tax rate on the i-th agricultural output.

Then agricultural income is given by

$$Y_{At} = \sum_{i\varepsilon A} \{[y_{it}(1-t_i)-q_{it}]p_{it}^r + q_{it}p_{it}^*\}(1-\theta) \tag{4.1}$$

Given the outputs y_{it}, the government controls agricultural income by controlling t_i, q_{it} and p_{it}^*. Rural income Y_{rt} includes both agricultural income and income from industrial sideline activities. To estimate the latter, let ψ_i denote the fraction of industrial outputs i produced by the rural sideline activities times the corresponding ratios of incomes to revenues and assume that the incomes obtained from these products will all accrue to the rural population. Total rural income will then be, with In denoting the set of industrial products,

$$Y_{rt} = Y_{At} + \sum_{i\varepsilon In} \psi_i y_{it} p_{it}^r \tag{4.2}$$

To exercise control over urban income, the government sets the wage rates w_j for different categories of workers. If L_j denotes the number of urban workers

in the j-th category, urban income is essentially $\sum_j w_j L_j$, ignoring interest payments from bank deposits. If the prices p_{it}^r and p_{it}^u of consumer goods in rural and urban areas are to remain stable, the total incomes in these areas must not exceed significantly the values of the consumer goods available. Let γ_r and γ_u respectively be the fractions of income consumed by the rural and urban populations. The government planners must set the purchase prices and quotas for agricultural products and the wage rates for the workers in such a way that the following two equations hold

$$\gamma_r Y_{rt} = \sum_{i=1}^{m} c_{it}^r p_{it}^r \qquad (4.3)$$

$$\gamma_u Y_{ut} = \gamma_u \sum_j w_j L_j = \sum_{i=1}^{m} c_{it}^u p_{it}^u \qquad (4.4)$$

where Y_{rt} is explained by equations (4.1) and (4.2); and c_{it}^r and c_{it}^u are explained by the model (3.9) in Section 3.

The reader should note that the purpose of setting up equations (3.1) through (3.3) in Section 3 was to provide an approximate system of linear equations to determine the outputs of m-1 consumer goods (in rural and urban areas) in terms of the output of one consumer good, c_1^r and c_1^u. We treated the _relative_ prices p_j in (3.1) as given constants, in order to obtain the coefficients in (3.3) for the calculation of $C_2, \ldots, C_m$ in terms of C_1 (superscript r or u omitted). Once the outputs $C_1, \ldots, C_m$ are determined, as discussed at the end of Section 3, one could use (3.1) as a system of equations to determine the relative prices $p_1, \ldots, p_m$ if it is an accurate system of demand equations. However, one can improve the scheme for determining the relative prices in the economy by using a possibly nonlinear system of demand equations.

Let the rural demand equations for consumption goods be

$$c_{it}^r = c_i^r(Y_{rt}/p_{rt}, \; p_{1t}^r/p_{rt}, \ldots, p_{mt}^r/p_{rt}) \qquad (i=1,\ldots,m) \qquad (4.5)$$

where $p_{rt} = \sum_{i=1}^{} \delta_{ri} p_{it}^r$ is a price index of consumption goods in the rural areas. Let the urban demand equations be

$$c_{it}^u = c_i^u(Y_{ut}/p_{ut}, \; p_{1t}^u/p_{ut}, \ldots, p_{mt}^u/p_{ut}) \qquad (i=1,\ldots,m) \qquad (4.6)$$

where $p_{ut} = \sum_{i=1}^{} \delta_{ui} p_{it}^u$ is a price index of consumption goods in the urban areas. There is a rich literature on systems of demand equations derived explicitly from the theory of consumer behavior, and several attractive functional forms are available. See Deaton and Muellbauer (1980) for a recent attempt and some important references. If the price indices p_{rt} and p_{ut} are known and if the rural and urban incomes are given by (4.2) and $\sum_j w_j L_j$ respectively, we can solve equations (4.5) and (4.6) to obtain the relative prices p_{it}^r/p_{rt} and p_{it}^u/p_{ut} of the rural and urban consumption goods which would prevail if the markets are free and the supplies c_{it}^r and c_{it}^u are determined by the model (3.9).

In China, however, a number of goods are rationed. Under this system, the quantities C_{it} and prices p_{it} of the rationed goods $(i=1,\ldots,m_1)$ are given. Assuming that rationing is effective, the income remaining for the purchases of non-rationed goods will be, for the rural and urban populations respectively,

$$Y_{rt}^* = Y_{rt} - \sum_{i=1}^{m_1} p_{it}^r c_{it}^r \qquad (4.7)$$

$$Y_{ut}^* = Y_{ut} - \sum_{i=1}^{m_1} p_{it}^u c_{it}^u \qquad (4.8)$$

A system of $m-m_1$ demand equations, analogous to (4.5) and (4.6) with Y_{rt}^* and Y_{ut}^* replacing Y_{rt} and Y_{ut} as income variables, can be used to find the relative prices of the remaining goods $(i=m_1+1,\ldots,m)$.

Once the relative prices of consumption goods are determined, with or without rationing, the absolute prices of these goods will be determined if the price indices p_{rt} and p_{ut} are known. These price indices can be found by equating the purchasing power with the total value of consumption goods available in the rural and urban areas. That is to say, they are determined by

$$\gamma_r Y_{rt} = p_{rt} \sum_{i=1}^{m} c_{it}^r (p_{it}^r / p_{rt}) \tag{4.9}$$

$$\gamma_u Y_{ut} = p_{ut} \sum_{i=1}^{m} c_{it}^u (p_{it}^u / p_{ut}) \tag{4.10}$$

where, as we recall, Y_{rt} and Y_{ut} are subject to government control through fixing the purchase quotas and prices of farm products and the wage rates, c_{it}^r are determined by the model (3.9), and the relative prices (p_{it}^r / p_{rt}) and (p_{it}^u / p_{ut}) are determined by equations (4.5) and (4.6), or a subset of $m-m_1$ of them determined by equations analogous to (4.5) and (4.6), leaving only the variables p_{rt} and p_{ut} to be determined. Even if the prices of the rationed goods are fixed, equations (4.9) and (4.10) remain valid. The price indexes p_{rt} and p_{ut} will still go up when money incomes Y_{rt} and Y_{ut} go up as a result of government policies on purchase prices of farm products and on wage rates. The main difference is that the pressures on prices will fall mainly on the remaining goods whose prices are not fixed. For the prices that are fixed, there will be shortages and/or hidden inflation, with higher prices prevailing in the black markets. China has been experiencing some inflation in 1980-1981.

It should be remarked here that when rationing is introduced so that the purchases c_{it}^r and c_{it}^u are restricted by the numbers of ration coupons issued according to the limited supplies, there is really no need to control the prices of the rationed goods. Their relative prices can be determined by equations (4.5) and (4.6). Their absolute prices will be determined by equations (4.9)

and (4.10), and inflation can be controlled by controlling Y_{rt} and Y_{ut}.

This may be the appropriate place to comment on two aspects of the current economic reform contemplated by some economic planners of the Chinese government. The first is the possible reduction of the number of rationed commodities and the decontrol of certain prices. As we have just pointed out, absolute prices p_{rt} and p_{ut} are determined by equations (4.9) and (4.10), increasing as money incomes Y_{rt} and Y_{ut} increase. Once the purchasing power is restricted by controlling Y_{rt} and Y_{ut}, there is no need to control the individual prices in order to prevent inflation. Relative prices of commodities in short supply will go up so that consumers will economize on their use.

The second aspect of the current economic reform is to give the producers more discretion and incentives to produce their products, including private plots for the farmers and certain degrees of autonomy and percentage profit retention for the managers of enterprises. These reforms will have the effects of increasing productivity beyond the description of our input-output model. By working harder, the farmers can produce more without the input-output statistician noticing any changes in the recorded quantities of inputs. Any input-output relations estimated from current data are based on the current institutions governing production. If the institutions change significantly, the input-output table should be changed. Furthermore, the input-output model is well suited for a command economy where the central planners control the outputs of most industries by issuing production quotas or targets to the farmers and managers of enterprises, as it has been the case in China. We have assumed that the final outputs can be planned by the central planners, explicitly or implicitly, through a dynamic input-output model as described in Sections 2 and 3, so that given any plan, the final outputs y_{it} can be so calculated. Such an analysis does not take into account the additional production incentives to be provided by the price

mechanism. For example, the farmers in PRC operating their private plots will behave like the farmers in Taiwan; they will grow more of certain crops when the (relative) prices of those crops increase. In fact, the supply of pork in China did increase tremendously in 1980 as a result of the increase in purchase price. From the viewpoint of modelling, a set of supply functions showing the quantities supplied according to the relative prices of the outputs would replace the fixed supplies C_{it}. These supply functions, together with the demand functions (4.5) and (4.6) would determine the relative prices prevailing in the free markets, while the price indices of consumption goods remain to be determined by equations (4.9) and (4.10).

5. GOVERNMENT REVENUES AND EXPENDITURES

In setting the purchase prices of farm products and the wage rates, the government has to consider the restrictions of its budget. Increasing the purchase prices and wage rates will result in more government expenditures and less government revenues respectively, both requiring increasing receipts from other sources or reducing expenditures on other items, if the government budget is to be balanced. In this section, we discuss revenues and expenditures of the Chinese government.

Table 2 gives the estimates of government revenues and expenditures in 1980 as announced by the Chinese government in September 1980. It shows that 43.3 percent of total revenues are revenues of enterprises, to be denoted by R_E. Since government enterprises account for a large fraction ρ (over 80 percent) of industrial outputs, we have approximately

$$R_{Et} = \sum_{i \in In} (p_i y_{it} - \sum_j w_j L_{jt}) \rho \qquad (5.1)$$

TABLE 2

Estimates of Chinese Government Revenues and Expenditures in 1980*

Revenues (billion yuans)		%
Revenues of enterprises	46.06	43.4
Taxes	54.40	51.2
Other revenues	.24	.2
Dep. allow. of central enterpr.	2.20	2.1
Foreign loans	3.39	3.2
Total	106.29	100.00

Expenditures (billion yuans)		%
Construction	37.35	32.7
Enterprise renovations + innovations	6.98	6.1
Enterpr. working capital + bank loans	3.72	3.3
Farm subsidies + other expenditures	7.74	6.8
Education, Health and Science	14.83	13.0
Defense	19.33	16.9
Administration	5.78	5.1
Development of backward areas	.50	.4
Reserve funds	1.88	1.6
Interest + repayment of foreign loans	2.17	1.9
Total	114.29	100.00

* Source: People's Daily, September 13, 1980.

We subtract from the revenues of final products the total payment to labor to obtain the total revenues accrued to the government (part of which is remitted to the central government and the remaining part is left to the provincial and municipal governments, but all within the control of the national budget). A fraction ϕ_i can be inserted as a factor multiplying the gross revenue $p_i y_{it}$ to allow for other expenses than wage payments, if necessary. One point to note in (5.1) is that, by increasing the wage rates w_j, the government will have less revenues from enterprises. If the enterprises are allowed to retain parts of their revenues for reinvestment and other uses as suggested by recent reforms, a fraction λ_{it} should multiply the right side of (5.1). An equation explaining enterprise investment might be needed.[1]

The major category of revenues, some 51.2 percent in 1980, consists of taxes on production and sales of various commodities, such as the salt tax, tax on agricultural and industrial products. Total taxes T are explained by

$$T_t = \sum_i t_i y_{it} p_{it} \tag{5.2}$$

as a crude approximation, where the tax rates t_i are treated as given. We treat total revenue R_t as the sum of four items

$$R_t = R_{Et} + T_t + DA_t + FL_t \tag{5.3}$$

where depreciation allowances DA_t of centrally administered enterprises and foreign loans FL_t are exogenous variables.

On the expenditures side, the first three items given in Table 2 include construction and other investment expenditures. These items, in physical units, are explained by our model (3.9) in the vector I_t. Money expenditures for them can be estimated simply by multiplying I_t by the corresponding prices. Note that our model is concerned only with total investment expenditures, leaving unanswered the question as to who (the central government, provincial or local governments

or the individual enterprises themselves) should carry out what proportions of the total investment. Whether the central planning authority (the Planning Commission of the State Council in China) decides to execute the investment projects itself or leave them to the initiative of the individual enterprises, it should have an overall picture of the total national resource available for consumption and investment, as not to make plans which are beyond the productivity capabilities of the national economy. The next item, farm subsidies and other expenditures, is dependent on the purchase prices (as compared with the ration prices or the market prices) and purchase quotas of farm products. Given the ration prices or the market prices of the farm products, increasing the purchase prices paid to farmers will increase government farm subsidies which equal $\sum_{i \in A} q_{it}(p_{it}^* - p_{it}^u)$.

Expenditures (in real terms) on Education, Health and Scientific Research and on government administration are also explained by the model (3.9). Money expenditures are obtained by conversion with the appropriate price indices. Defense is explained likewise, once the control variables of model (3.9) are given. The last three items in the list of expenditures on Table 2 are treated as exogenous. Thus all items of expenditures are determined by our model.

Given the tax rates and wage rates, our model also determines the total revenues of the government by determining the outputs y_{it}. While the expenditure items are subject to the control of the government as we have explained in Section 3, the resulting expenditures need not produce a balanced budget. For example, in 1980, the estimated deficit according to Table 2 amounted to 8 billion yuans. Using the econometric model, the government should be able to predict the likely consequences of its policies. Anticipating a deficit if expenditures remain the same (and the rising prices associated with it because of the excesses of money demands by consumers and government over the available supply

rural and urban populations and the prices of consumption goods. The third, consisting of equations (5.1) to (5.4), determines government revenues and expenditures and, assuming a balanced budget, restricts the government's choice of the values for the control variables. The control variables include c_{1t}^r, c_{1t}^u, G_{1t} and D_{kt} which control the resources devoted to rural consumption, urban consumption, government consumption and defense. Although the government can control the purchase quotas q_{it}, the purchase prices p_{it}^*, the wage rates w_{it}, the tax rates t_i, as well as the prices of many producer and consumer goods, it will be preferable to treat them as parameters rather than control variables when we study the dynamic properties of the model under control since they should not be changed frequently, and for the quotas q_{it}, smooth trends should be assumed.

At the end of Section 3, we have discussed the applications of the physical part of our model. With the addition of the last two parts to the model, we can trace out the paths of incomes, prices and government revenues and expenditures through time. This would provide the economic planners with additional information on the likely economic consequences of their policies.

There are two ways to use the model outlined in this paper in the formulation of economic policies. One is to try out certain hypothetical policies, such as increasing the control variables c_{1t}^r, c_{1t}^u, G_{1t} and D_{kt} by one percent per year, and calculate the paths of investments, capital stocks, unemployment, and the price indices through time using the econometric model. The planner can choose that policy which, according to the model, will generate the most desirable economic consequences. This method is unsystematic. One may miss trying out some better policies. Even for the policies actually tried, the economic consequences involving the time paths of many economic variables are complicated and difficult to compare. Therefore, we recommend a second and more systematic approach to the selection of economic policies by the use of optimal control methods.

of goods at existing prices), the government planning authority may decide to reduce its expenditures.

It is interesting to note that Deputy Prime Minister Yao Yilin, Chairman of the State Planning Commission, in a speech before the Standing Committee of the National People's Congress on February 25, 1981 (summarized in New York Times, March 1, 1981, p. 1; Wall Street Journal, March 9, 1981, p. 27; with full text appearing in Ta Kung Pao, March 8, 1981, p. 2), reported a government deficit of 12.1 billion yuan, 4.1 billion over the estimate made in September 1980, and announced his plan to achieve a balanced budget at 97.6 billion in 1981 by reducing basic construction and investment expenditures from the original 55 billion to 30 billion. The 4.1 billion figure resulted partly from excesses of the actual over the planned figures in construction and investment (2 billion), farm subsidies (.6 billion), administration (1.0 billion), and Education, Health and Science (.9 billion). If the Chinese government intends to run a balanced budget, deficit DF is zero in an equation equating total revenues and expenditures. This would provide an additional equation to our model which would restrict the government choices of its control variables G_l and D_k, given the farm purchase prices p_i^*, the wage rates w_i, and the tax rates t_i:

$$R_t + DF_t = \sum_i I_{it} p_{it} + \sum_{i \varepsilon A} q_{it}(p_{it}^* - p_{it}^u) + \sum_i G_{it} p_{it} + \sum_i D_{it} p_{it} \qquad (5.4)$$

6. USES OF THE MODEL FOR PLANNING

Our model consists of three sets of equations. The first, summarized by (3.9), determines the physical quantities of production and investment in various industries. The second consisting of (4.1), (4.2), (4.5), (4.6), or the analogue of (4.5)-(4.6) under rationing, (4.9) and (4.10), determines total incomes of the

of the first problem but the target path for consumption is set higher. We assign
very heavy penalty weights to all variables except defense. The solution of the
second optimal control problem will yield higher consumption levels and approx-
imately the same capital stock growths and the same price levels because of the
high penalties, but will result in smaller outputs for defense. Thus the trade-
off relation between consumption and defense can be traced out by using optimal
control methods. Similar methods have been applied in Chapter 7 of Chow (1981)
to trace out the trade-off relations between unemployment and inflation in the
United States using two econometric models of the United States economy. These
methods can be applied to find the trade-off between any two important variables
for Chinese economic planning.

Until recently, when linear input-output models were used for economic plan-
ning, the optimalization technique employed was linear programming which assumes
a linear objective function. As reported by Taylor (1975, pp. 88-89), and cer-
tainly expected from the nature of the optimization problem, the linear program-
ming solutions of a multiperiod planning problem led to the concentration of
consumptions in one year. A quadratic objective function is more suitable for
this problem, and linear-quadratic control theory provides the necessary tools
for optimization. Furthermore, parts of the model may be nonlinear, as the demand
equations (4.5) and (4.6) of Section 4. Random disturbances will affect the econ-
omy as weather conditions will affect agricultural output beyond the description
of a deterministic input-output model. To deal with optimal planning over time
using a nonlinear stochastic model, the methods of stochastic control will be
useful. The solution to such optimization problem takes the form of feedback
control equations which recommend an optimal strategy in period t based on the
random events occuring up to period t-1. Although a five-year plan announced in
year 1 contains projections of all economic variables including the control

To apply optimal control, one first defines an objective function which includes the time paths of the important economic variables as arguments. For example, one may wish to specify that the above four control variables should ideally increase by 4 percent per year, that the paths of capital stocks should increase by 5 percent per year, while the two price indices should remain constant. These ideal objectives may not be achievable simultaneously; if they were, the planner should raise his aspirations and aim at better targets. According to the relative importance of meeting the targets, one assigns penalty weights to the squared deviations of these variables from their targets, and obtains a measure of welfare loss which is to be minimized by choosing the time paths of the control variables. Optimal control methods are used to find the time paths of the control variables which will minimize the values of a given loss function, subject to the constraint of the econometric model. These methods and their economic applications are discussed in Chow (1975) and Chow (1981). In particular, Chapters 10, 12 and 13 of Chow (1981) deal respectively with the applications of control methods to the solution of a problem of economic planning in Taiwan, to the formulation of economic policies in a western country such as the United States, and to the analysis of economic planning in the Soviet Union.

One interesting application to the economic planning of PRC is to find out how much consumption has to be sacrificed in order to strengthen defense, assuming the growth of capital stocks and the price indices remain the same. We start by using a loss function which penalizes the deviations of consumption, defense, capital stocks and the price levels from their respective target paths, and solving an optimal control problem to obtain the paths of these four variables that can be achieved.[2] If the solution paths of these variables are satisfactory, we solve a second optimal control problem. In this problem, the target paths for defense, capital stocks and the price levels are set equal to the solution paths

draft of this paper, without implying that they necessarily agree to the views expressed herein. Financial support from the National Science Foundation, Grant No. SES80-12582, is gratefully acknowledged.

FOOTNOTES

[1] As more economic decisions are left to units other than the central government, more components of final demand in equation (3.4) will be explained endogenously by decentralized decisions. The economy may become more efficient and the input-output coefficients may have to be revised.

[2] The balance of trade can be an additional target variable, in which case we need an equation explaining trade deficit as the excess of the values of imports over exports. Our model explains imports endogenously and treats exports as exogenous variables, but some components of exports can be treated as control variables as well. These changes can easily be incorporated in the methodological discussion that follows.

variables for five years, the policies to be actually implemented in years 2, 3, 4 and 5 will depend on what shall have occurred up to that time in order to compensate for the effects of unforeseen events. Hence stochastic control methods appear to be the natural tools to use for economic planning.

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