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PROGRAMMING THE RELATIONSHIP BETWEEN THE AGRICULTURAL AND INDUSTRIAL SECTORS IN A PLANNED ECONOMY

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1. INTRODUCTION

The model of the present paper divides a planned economy in two sectors: the agricultural sector and the industrial sector. The class of two-sector models contains many other members: producer goods/consumer goods; heavy/light industries; internationally traded commodities/goods and services produced and consumed within the country; Government/private sector; modern/traditional industries. This particular choice was made in order to throw light on the economic relationships governing the supply of food to the urban population. In any country except the most highly industrialized this commodity flow originates for the greater part within the country itself, and is an important component of the national product.

Cutting an economy in two and calling the two halves "agricultural" and "industrial" sectors is a gross simplication. Agricultural output consists of more than food alone, and rural output embraces even more goods and services. Nevertheless, we shall use the words "food", "agricultural" and "rural" without distinction, and similarly, we shall equate urban output to industrial production. Other simplifications will become evident below.

In all planned economies, some part of the supplies of food to the cities is planned, or contracted, in advance, both as to quantities and as to prices. The purpose is to secure a dependable supply of basic foods at reasonable prices; an accidental consequence is the provision of a secured minimum money income to the farm population. The remainder is sold more or less freely at the prices the urban consumers are willing to pay. The quantities so sold depend on the weather, but also on the price: higher prices induce the farmers to grow more, and to sell a greater part of their output.

The paper analyzes the consequences of a limited reduction of contracted supplies, assuming an optimal planning of the financial balances involved. The context is a hypothetical country of 10 million inhabitants that has just drawn up a Plan for the years 1971-1975. The reduction in contracted supplies is supposed to be divided over these five years.

2. MAIN PLAN TOTALS

The main totals for 1970 and 1975 are represented in the sector accounts below. All flows are expressed in billions of dollars, and the prices are those of 1975.

Agricultural Sector

Outlay	1970	1975	Income	1970	1975
RCF rural food consumption	3.00	3.55	RCF rural food consumption	3.00	3.55
RCM rural consumption of manufactures	1.30	1.60	CTR contracted supplies	1.60	1.70
- tax on same	0.65	0.75	FFM food sold on free market	0.85	1.30
ISA industrial supplies to agriculture	0.50	0.65	FEX net food exports	-	-
			FPR food production	5.45	6.55
			ABN net credits received	-	-
	5.45	6.55		5.45	6.55

Rural food consumption RCF includes the food consumed at the farm, valued at the average prices received for food actually sold. Net credits received ABN are nil because the increase in money held exactly matches the rise in bank loans outstanding.

Manufacturing

Outlay	1970	1975	Income	1970	1975
MWF manufacturing wage fund	4.30	5.95	UCM urban consumption of manufactures	2.20	3.40
CAP capital goods received	1.00	1.40	RCM rural consumption of manufactures	1.30	1.60
			CAP capital goods supplied	1.00	1.40
			ISA industrial supplies to agriculture	0.50	0.65
			MEX net exports of manufactures	-	-
			IPR industrial production	5.00	7.05
			MBN net credits received	0.30	0.30
	5.30	7.35		5.30	7.35

The fact that net credits received by the manufacturing sector MBN do not rise between 1970 and 1975 reflects an increasing dependence on internal sources of finance.

In the urban sector it is helpful to specify a separate consumer sector.

Urban consumers

Outlay	1970	1975	Income	1970	1975
UCM urban consumption of manufactures	2.20	3.40	MWF manufacturing wage fund	4.30	5.95
- tax on same	1.10	1.60	GCP government current payments	1.45	2.05
CTR contracted food	1.60	1.70			
FFM food bought on free market	0.85	1.30			
	5.75	8.00		5.75	8.00

It is assumed that consumers pay the same amounts for contracted food and for food bought on the free market that the agricultural sector receives.

Government

Outlay	1970	1975	Income	1970	1975
GCP current payments	1.45	2.05	- tax on consumption of manufactures:		
			urban	1.10	1.60
			rural	0.65	0.75
			ABN net credits received	-0.30	-0.30
	1.45	2.05		1.45	2.05

Rest of the world

Outlay	1970	1975		1970	1975
MEX net manufacturing exports	-	-	FBN net credits received	-	-
FEX net food exports	-	-			
	-	-		-	-

It will be found that the net credits received by four sectors, ABN, MBN, GBN, and FBN, add up to zero: the banking system must be in equilibrium.

It is assumed that the Plan incorporates the highest estimates the planners believed feasible for investment CAP, and for industrial supplies to the agricultural sector ISA.

3. THE MODEL

The model consists of 14 linear equations representing the relationships between 14 endogenous and 12 exogenous variables in 1975. The greater part of these have already been mentioned in the sector accounts. Prices did not occur there, however. These are measured as fractional changes with respect to the levels in 1975. One example may suffice to explain these units: if a certain price index is expected to have a value of 140 points in 1975, then a change to 154 points means a fractional change of 14/140 = 0.10 which is the value the price variable concerned will assume.

Alphabetical lists of all the variables follow. It will be observed that all price changes have symbols beginning with P.

Endogenous variables	Values in 1975	Exogenous variables	Values in 1975
ABN net credits received by agriculture	-	CAP capital goods supplied	1.40
FBN net credits received by rest of the world	-	CTR contracted food supplies	1.70
FFM food sold on free market	1.30	FEX net food exports	-
FPR food production	6.55	GCP Government current payments	2.05
GBN net credits received by Government	-0.30	ISA industrial supplies to agriculture	0.65
IPR industrial production	7.05	MEX net exports of manufactures	-
MBN net credits received by manufacturing	0.30	MWF manufacturing wage fund	5.95
MPR material production	13.60	prices of -	
PFM prices of free market food	-	PCF contracted food paid by consumers	-
RCF rural consumption of food	3.55	PCI manufactured consumer goods received by industry	-
RCM rural consumption of manufactures	1.60	PCT contracted food received by agriculture	-
RSL rural standard of living	5.15	PMC manufactured consumer goods paid by consumers	-
UCM urban consumption of manufactures	3.40	PSA industrial supplies to agriculture	-
USL urban standard of living	6.40		

Of the five sectors balances shown above, the first two give each rise to two balance equations (using as intermediate totals FPR and IPR), while the other three lead to one equation each, or seven balance equations in all. These follow below.

(1) FPR = RCF + CTR + FFM + FEX

(2) IPR = UCM + RCM + ISA + CAP + MEX

(3) FEX + MEX = FBN

(4) IPR + 5.00 PCI + 0.65 PSA = MWF + CAP - MBN

(5) FPR + 1.70 PCT + 1.30 PFM = RCF + ISA + RCM + 2.35 PMC + 0.65 PSA - ABN + 0.75

(6) 1.70 (PCF - PCT) + 7.35 PMC - 5.00 PCI + 2.35 = GCP - GBN

(7) MWF + GCP = CTR + FFM + UCM + 1.70 PCF + 1.30 PFM + 5.00 PMC + 1.60

A term like 0.65 PSA (in equation 4) will become clear by reference to the value of industrial supplies to agriculture ISA in 1975, which is 0.65 billions. A fractional change in the prices of these supplies PSA increases the income of manufacturing by 0.65 PSA billions.

It will be seen that an algebraic summation of the 7 balance equations leads to the equation

$$ABN + FBN + GBN + MBN = 0$$

stating that the banking system must be in equilibrium. This equation is dependent on the other 7 and should therefore not be included in the model. The following four equations are technological and behaviour equations which require separate discussion.

(8) $$IPR = 1.00\ CAP + 5.65$$

This is an industrial production function that explains marginal industrial output as the result of marginal supplies of capital goods. The coefficient 1.00 is explained as follows.

It is assumed that an additional unit of capital goods supplied in 1975 corresponds to gradually increasing, additional supplies in each of the years of the planning period, in particular

0.0 units in 1970
0.2 units in 1971
0.4 units in 1972
0.6 units in 1973
0.8 units in 1974
1.0 unit in 1975

As there is a lag between the supply of capital goods and the resulting increase in industrial output, not all these additional supplies will contribute to the output of 1975. A reasonable assumption might be that the additional supplies in the five years 1970-1974, totalling 0.0 + 0.2 + 0.4 + 0.6 + 0.8 = 2.0 units, do indeed contribute. An incremental capital-output ratio of 2.0 would require 2.0 units of additional capital goods in order to produce one unit of manufactures annually. The 2.0 units additionally supplied in 1970-1974 supposing an increase in CAP of 1.0 unit in 1975 would thus lead to 1.0 unit more industrial output IPR in 1975, hence the coefficient of 1.0.

The constant 5.65 is derived by substitution of the 1975 values of IPR and CAP.

(9) $$FPR = 1.00\ ISA + 3.28\ (PFM - PMC) + 5.90$$

This agricultural supply function is somewhat more complicated because the price incentive plays a rôle in it. The industrial supplies to agriculture ISA consist largely of capital goods, which affect output FPR in the same way as investment CAP affects industrial output IPR. For the remaining part, the industrial supplies are directly related to agricultural output: fertilizer increases output, tractor fuel is a necessary input. The coefficient of ISA is arbitrarily put at the same value as the coefficient of CAP in equation (7). There are reasons for both a higher and a lower value.

The price incentive is expressed by means of the difference between changes in prices for food sold in the free market PFM and changes in prices of industrial consumer goods PMC. Prices of contracted supplies play no part here, because the amount of those supplies cannot be varied by the agricultural producers. If food prices PFM rose and prices of consumer goods PMC increased by the same percentage, the yield of additional food output, in terms of the additional consumer goods for which it could be exchanged, would remain constant, and there would be no incentive to increase food production.

Little is known about the reaction of farmers to price changes. In certain situations a negative effect is even supposed to exist: the farmers would aim at a given amount of consumer goods and once this amount could be bought, an increase in output prices would cause them to reduce output, because less would now be needed to purchase the fixed amount of consumer goods set as a target. There is, however, little evidence that even the most primitive farmers indeed react in this way, and we shall suppose that the supply elasticity is clearly positive, namely 0.5.

Such an elasticity means that a one percent change in prices causes half of a percent change in output, that is, if PFM = 0.01, then FPR must increase by $0.5 \times 0.01 \times 6.55 = 0.0328$ billion (it will be remembered that FPR amounts to 6.55 billion in 1975). The coefficient in the linear relationship will thus equal $0.0328/0.01 = 3.28$

(10) $$FFM = 0.10\ (MWF + GCP - CTR - 1.70\ PCF - 5.00\ PMC) - 0.65\ (PFM - PMC) - 0.50\ CTR + 1.52$$

This equation represents the demand function for food in the free market. Three factors are distinguished: disposable income, relative prices, and available basic food supply.

Disposable income equals gross income MWF + GCP minus the amounts that are taken up by the basic food supply CTR and by increases in prices of CTR and of manufacturing products, these price changes being weighted by the amounts to which they are applied. Other definitions are possible; the present one tries to approximate the amount the urban consumers can choose to spend on free market food or on other things. In 1975, the disposable income so defined amounts to 6.30 billions. A demand elasticity with respect to income of 0.5 looks reasonable for food that excludes the most basic food items. The coefficient is thus found to be $0.5 + 1.30/6.30 = 0.10$.

Price changes of food and manufactured consumer goods, PFM and PMC, are opposed in order to obtain relative price changes of food with respect to competing consumer outlay. The elasticity regarding these relative price changes is put at -0.5.

It is reasonable to assume that a reduction in contracted supplies CTR increases demand for free market food, but for only part of the amount of the reduction. This is represented by the term -0.50 CTR

(11) $$FFM = 0.13\ (FPR - CTR - FEX) + 0.65\ (PFM - PMC) + 0.67$$

The fourth behaviour equation is the supply equation for free market food. The farmers have at their disposal the current food production FPR, minus the contracted supplies CTR and the net exports FEX; they may choose between selling more in the free food market, or consuming more themselves. The supply elasticity with respect to available quantity is supposed to equal 0.5. In 1975, the quantity FPR - CTR - FEX amounted to 4.85 billions, while FFM equalled 1.30 billions. The coefficient thus becomes $0.5 \times 1.30/4.85 = 0.13$.

Prices of food sold in the free market and prices of manufactured consumer goods that can be bought in exchange affect the distribution of the disposable food over sales in the market, and own consumption. The elasticity is again assumed to equal 0.5.

There remain three definitions defining the target variables MPR, USL and RSL.

(12) $$MPR = FPR + IPR$$

(13) $$USL = UCM + CTR + FFM$$

(14) $$RSL = RCM + RCF$$

Material product MPR is an obvious target; for some planners it may even be the only target worth mentioning.

The urban standard of living USL is defined as the sum of the amounts of consumer goods the urban population buys. Obviously, other factors affect the standard of living, but these are not variable within the context of the model. The distribution of total consumption over the three components is not supposed to affect the standard of living. This is only proper if a market equilibrium exists so that the consumer can freely allocate a marginal amount of purchasing power to any of the three components. Rationing and shortages may interfere with equilibrium in this sense, and in that case rationed commodities are worth more to the consumer than their price indicates.

The rural standard of living RSL is likewise defined as total rural consumption.

4. THE REDUCED FORM

The system of 14 linear equations in 14 endogenous variables, 12 exogenous variables, and some constants allows us to express the endogenous variables as linear functions of the exogenous variables and the constants. In formulas, if

$$Ay = Bx + c$$

represents the system, with y for the vector of endogenous variables, x for the exogenous variables and c for the constants, with A and B as coefficient matrices, then

$$y = A^{-1}Bx + A^{-1}c$$

The matrix $A^{-1}B$ is usually called the "reduced form". In the present model, it has 14 rows and 12 columns. Three of its rows are shown below.

Endogenous variables	Exogenous variables											
	CAP	CTR	FEX	GCP	ISA	MEX	MWF	PIF	PCI	PCT	PMC	PSA
MPR	1.00	-0.89	0.25	0.19	0.75	-	0.19	-0.32	-	-	-0.95	-
RSL	-	-1.25	-0.66	-0.74	-0.35	-1.00	-0.74	1.25	-	-	4.97	-
USL	-	0.35	-0.10	0.93	0.10	-	0.93	-1.57	-	-	-5.92	-

As an example, let us consider the column GCP (Government current payments). If these payments are increased by 1 million, the urban consumer has 1 million more to spend. Most of this will be spent on manufactures, but some will find its way to the free food market, where prices will rise. As a result, the agricultural sector will produce somewhat more, so that the material product MPR increases by 0.19 million. The additional urban expenditure on manufactured consumer goods has the obvious effect that less of the supply will remain available for the rural population. This causes RSL to decline by 0.74 million. At the same time, the Government has to pay 1 million more, for which it draws upon credit. The banking system reduces its net loans to agriculture by 1 million, and the financial balances of both the banks and the rural sector are in equilibrium again.

5. A PROGRAMMING EXPERIMENT

By means of the reduced form we can now try to improve upon the provisional five-year plan, making a judicious use of some exogenous variables as policy instruments. Any of the three target variables may be increased as long as the other two do not suffer. The reduced form shows that most exogenous variables, when separately used as policy instruments, increase some target variable and reduce another one simultaneously. Only CAP and MEX form exceptions. However, to raise CAP, the supply of capital goods to manufacturing, as a means to increase industrial output, is not exactly a new idea, and we have already assumed that the Plan incorporated the highest estimates the planners believed feasible. Reducing MEX, exports of manufactures, as a means to increase the rural standard of living would leave a deficit on the balance of

payments which other countries may not be willing to finance. Apparently, combinations of two or more instruments are required.

These can be found by means of linear programming. Either MPR, RSL or USL can be maximized, or any linear combinations of these target variables with non-negative coefficients. Constraints can be placed on each of the exogenous variables; for instance, $\Delta CAP \leqq 0$ is a constraint saying that the capital goods supply to manufacturing cannot be further increased. In addition, constraints can be put on endogenous variables; for instance, $\Delta MPR \leqq 0$ means that the material product should never be decreased, and $\Delta FBN = 0$ means that the balance of payments should neither show a deficit nor a surplus.

A result of such linear programming experiments is the suggestion to reduce CTR, contracted food supplies, by 10 percent, that is 0.170 billion, and to raise the manufacturing wage fund MWF by 0.065 billion, or 1.1 percent. The effect of such a policy change is shown in the following table.

Endogenous variables	Columns of reduced form		-0.170 × col.(2)	0.065 × col.(3)	col.(4) + col.(5)
	CTR	MWF			
(1)	(2)	(3)	(4)	(5)	(6)
ABN	-	-1.00	-	-0.065	-0.065
FBN	-	-	-	-	-
FFM	-0.42	0.06	0.071	0.004	0.075
FPR	-0.89	0.19	0.151	0.012	0.163
GBN	-	-	-	-	-
IPR	-	-	-	-	-
MBN	-	1.00	-	0.065	0.065
MPR	-0.89	0.19	0.151	0.012	0.163
PFM	-0.27	0.06	0.046	0.004	0.050
RCF	-1.47	0.13	0.250	0.008	0.258
RCM	0.22	-0.86	-0.037	-0.056	-0.093
RSL	-1.25	-0.74	0.212	-0.048	0.164
UCM	-0.22	0.86	0.037	0.056	0.093
USL	0.35	0.93	-0.059	0.060	-

Columns (2) and (3) are taken from the reduced form, and show the effects of unit changes in CTR and MWF on all the endogenous variables. The combined effects of the two changes proposed is shown in the last column. Food production rises by 0.163 billion, and the entire advantage is transferred to the rural population.

It is perhaps somewhat surprising this is accompanied by a reduction in RCM, rural consumption of manufactures. The explanation lies in the fact that the urban population receives less basic food supplies CTR and only partly compensates for this by buying more food in the free market FFM. This leaves urban purchasing power available for purchases of manufactured consumer goods UCM, which then cannot be supplied to the rural population. The purchasing power of the rural population is lowered by the reduction in sales of food, both CTR and FFM, and by the decline in credits received, ABN. The latter is necessitated by the higher requirements for credit to manufacturing MBN which compensate the increases in wage fund payments MWF.

It will be obvious that other policies would also be conceivable. The example discussed above laid most stress on the rural standard of living RSL. If the stress is shifted to the urban standard of living USL, while the change in contracted food supplies CTR is maintained at -0.170 billion, another suggestion is obtained which is compared to the first in the table below.

	Main target	
	RSL	USL
Changes in instruments:		
CTR	-0.170	-0.170
MWF	+0.065	+0.288
Resulting changes in targets:		
MPR	+0.163	+0.206
RSL	+0.164	-
USL	-	+0.206

This alternative obtains a slightly higher increase in food output which entirely benefits the urban population. Linear interpolations between the two policies are, of course, possible.

The reduction of CTR by 170 million is supposed to maintain sufficiently the advantages of contracted food supplies, namely the guarantee of a dependable supply of basic food to the cities, and a minimum income for the farm sector.

6. CONCLUSION

The conclusion of this analysis by means of a two-sector model is that in this way it may be possible to discover feasible improvements in planned policies. No planner would, of course, accept the policy proposals above at their face value. Gross simplifications and crude assumptions abound in the analysis. But the general trend of the suggestions is that in a planned economy of this type, a limited reduction in contracted food supplies, coupled with an increase in wage payments, may benefit everybody and harm no one, and this may be followed up in detail by means of conventional planning processes.