

The Translation Problem in Technological Choice

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THE coining of a new term is an act of presumption and yet I am deliberately indulging in it with a view to focus attention on an important aspect of the problem of technological choice, the neglect of which in the current literature on the subject has, in my opinion, resulted in most theoretical results in the field having upto now found no application in actual planning work. The problem is as follows. Technological choice in practice has necessarily to be effected in respect of specific industries separately, and yet, in a planned economy, the choice has to be guided by optimality conditions holding for the economy as a whole. Thus, the choice may be between handloom or power loom in the textile industry, between country boats and mechanised boats in fishery or between hydro-electric energy and atomic energy in power generation, but the optimality conditions may be the maximisation of overall employment or of national income at the end of a period or of the rate of growth of the economy over a certain period. In current literature the problem is usually posed and treated in terms of a single sector. It is not always made clear whether the sector represents a single industry or a group of industries or the economy as a whole. Considering that frequently the criterion chosen is the maximisation of employment or income or surplus resulting from the given sector taken by itself, it would appear that the sector is identical with the entire economy; on the other hand illustrative figures are very often given from individual industries with the implication that the discussion refers to a single industry. Whether a single industry is considered or the whole economy, the results obtained for a single sector treatment are bereft; of usefulness from the application

point of view. For, if a single industry is considered, a choice that is optimum with respect to that sector alone cannot be also optimum for the economy as a whole (saving exceptional situations). On the other hand, if the sector is identical with the entire economy, then the results can only be tautological. For, the answer to the question, "What ought to be the choice so that certain overall conditions are satisfied?" can only be "That particular combination of techniques that lead to the said conditions being satisfied."

2. The only framework in which the translation problem can be tackled in practice is that of a "Perspective Plan. As we have already explained, the problem calls for the treatment; of sectors and industries individually as well as in their relations with the economy as a whole. Again, in the context of planned development, it is the effects of a choice over a long term that are important and not its immediate consequences. As sectoral interdependence in the process of growth and the fulfilment of some optimality conditions over a fairly long period of time are the essential features of a perspective plan, it is obvious that the translation problem of technological choice can be posed and solved only as a part of preparing a Perspective Plan.

3. We shall designate by the sequence P^1, P^2, P^3, \dots alternative possible Perspective Plans for a given long period (say 20 years). We shall conceive each such plan to consist of a number of Experts' Long-term Plans for different sectors of the economy exhibiting both Vertical and Horizontal Harmony. (I am using the terms Experts Long-term Plan, Vertical Harmony and Horizontal Harmony with the meanings given to them in my

article "Perspective Planning" in the *Economic Weekly* Special Number of July 1959; viz., 'a long-term plan prepared for a given single sector by experts in the field taking only technical and economic considerations applicable to the given sector'; 'harmony between the different elements belonging to such a plan'; and 'harmony as between different plans of this type'). We shall designate the different component Sectoral Long-term Plans (i.e. Expert's plans) of the Perspective Plan P^i_j by $P^i_1, P^i_2, \dots, P^i_N$ when N represents the number of sectors distinguished. Any sectoral plan P^i_j must incorporate a large number of specific choices in the matters of technology and organisation. We shall designate by T^i_j the whole complex combination of technological and organisational choices* associated with the sectoral plan P^i_j and call it a Combination. The problem of technological choice consists in choosing for a sector j a combination T^i_j such that it is possible to make on its basis a sectoral long-term plan P^i_j that could be fitted in an optimal Perspective Plan P^0 , that is a Perspective Plan satisfying certain given optimality conditions.

4. By its very definition, a Sectoral Long-term Plan (or an Experts Plan) cannot and does not take account of considerations holding for the economy taken as a whole. Perspective Planning has therefore necessarily got to be carried out through a process of adjustment and readjustment between the experts preparing the See-

* The choice with regard to organisation is equally important and poses a problem very similar to that of the choice of techniques. I have argued the case in my article "Investment allocation and Balanced Growth" in *Arthaniti*, vol. 1, No. 2. A simple example of how a change in organisation can affect the ratios connecting capital, output, employment, Surplus etc. is given by a change in the number, of shifts worked in an industry.

toral Plans and the planners preparing the Perspective Plan for the whole economy. In the Indian context, the experts will work in the different Ministries and the planners in the Planning Commission. Therefore, for shortness and concreteness, we shall refer to the parties in the process of adjustment and readjustment as the Planning Commission and the Ministries.† It is for the Planning Commission to lay down the overall criteria and it is for the Ministries to prepare Sectoral Long-term Plans so as to satisfy the criteria. The process, which is essentially one of trial and error, need not however reduce entirely to one of blind groping in the dark. It is the purpose of this article to suggest certain procedural rules which, if followed systematically, will lead to the desired result in a reasonably small number of steps. That is to say, the process of trial and error will be turned into one of iteration.

5. It is obvious from the above that by the time the problem of technological and organisational choice has been solved, satisfactorily, a satisfactory (in technical language, optimum) Perspective Plan would also have been drawn up. Hence, it is obvious, that the problems of investment allocation, inter-industrial balance, financial balance, balance of supply and demand of consumer goods etc. would also all have been simultaneously solved by the same procedure. We shall however in the present article concentrate mainly on the aspect of technological and organisational choice alone.

6. To start with, we have to decide upon the criterion that should guide choice. A criterion that has gained increasingly wide acceptance in planning literature is the maximisation of the rate of growth of the

† The Five Year Plans as worked out at present also involve a process of adjustment and readjustment between the Planning Commission and the Ministries, but (i) the Ministries do not all prepare any long term Plans of their own, (ii) they do not explicitly face the problem of choice of techniques and organisation and (iii) the Planning Commission does not follow any principle of optimality.

economy. For convenience, we shall translate the criterion into one of *maximising the overall "development outlay" of the plan over the entire plan period.* We understand the term "development outlay" in the sense of the official Indian planning terminology: it includes public and private sector investment and public sector non-investment developmental expenditure. Let D^i stand for this outlay and R^i the internal resource;,, both corresponding to the Perspective Plan P^i . Let F stand for external resources, which is the same, whatever be the Perspective Plan chosen. Then, obviously—

$$D^i + R^i = F$$

The resources R^i can be divided into two parts : a part R that would be available even if no fresh outlay at all is to take place, and an additional amount r^i which is an outcome of the plan r^i and which may be treated as proportional to D^i . We shall write—

$$R^i = R + r^i = R + D^i \theta^i$$

θ^i , which is the ratio of increased resources due to the plan to the total outlay on, the plan is dependent on the technological and organisational choices made with respect to the different sectors. θ^i can therefore be regarded as a coefficient completely determined by the combinations T_j^i ($j = 1, 2, \dots, N$). Now, as outlay must equal resources, we can write—

$$D^i = R + F = F + R + D^i \theta^i$$

$$\text{or } D^i = \frac{F + R}{1 - \theta^i}$$

so that D^i is an increasing function of θ^i . Maximisation of D^i is then equivalent to that of θ^i . The whole problem then reduces to choosing the Combinations T_j^i ($i = 1, 2, \dots, N$) in such a way as to maximise the resultant θ^i .

7. We shall now deduce conditions that must hold if the Combination in sector j is to be such as to conform to the optimum Perspective Plan, P^o . We shall designate by D_j^o and R_j^o the outlay on sector j and the plan resources arising from sector j respectively in the plan

P^o and by D_j^i and R_j^i the same in any other plan P^i . We shall further assume that the resources arising from sector j gets uniquely determined by the outlay on that sector and the technological-organisational combination chosen for the sector. That is, we shall assume that R_j^i is completely determined by D_j^i and T_j^i .

For the optimum plan P^o , we have $\theta^o = \frac{r^o}{D^o}$, where D^o is the total outlay on the plan P^o , and $r^o = R^o - R$. θ^o has to be a maximum for variations in the combinations T_j^i .

8. Let us consider a Perspective Plan P^i which differs from P^o in having a different technological organisational combination in sector j alone, the Combinations in all the other sectors being the same as in the optimum plan, P^o . That is to say $T_s^i = T_s^o$ for all s excepting $s = j$. Supposing that to maintain the same level of output in sector j as in P^o with Combination T_j^i instead of T_j^o it takes $\Delta^i D_j^o$ more of outlay in sector j and that the resultant increase in the contribution to resources from sector j is $\Delta^i r_j^o$. As the outlays on and the resources from the other sectors will be the same as before, we can write—

$$\theta^i = \frac{r^o + \Delta^i r_j^o}{D^o + \Delta^i D_j^o}$$

Hence the condition $\theta^i < \theta^o$ reduces to—

$$\frac{\Delta^i r_j^o}{\Delta^i D_j^o} < \frac{r^o}{D^o}$$

$$\text{or } \frac{\Delta^i r_j^o}{\Delta^i D_j^o} < \theta^o$$

From this result we can draw the following conclusion: a test of whether a perspective plan P^o is optimum or not is that it should not be possible to make any technological organisational change in any sector j involving an increase (or decrease) of $\Delta^i D_j^o$ in outlay and of $\Delta^i r_j^o$ in resources from sector j such that

$$\frac{\Delta^i r_j^o}{\Delta^i D_j^o} > \theta^o \left(\text{or } \frac{\Delta^i r_j^o}{\Delta^i D_j^o} < \theta^o \right)$$

9. The result just arrived at can be made use of to draw up a set of rules that may be followed to solve the problem of optimisation in a process of iteration. The rules simply lay down a series of steps to be taken alternately by the Planning Commission and the Ministries. They are as follows.

Step 1. The Planning Commission makes rough calculations with the help of some known values of macro-economic variables and coefficients and arrives at certain physical targets for each sector which are in balance with each other. The Planning Commission gives to each Ministry of the targets relevant to it and asks it to get its experts to prepare long-term plans for the sector or sectors under the jurisdiction of the Ministry for the realisation of the targets. The Planning Commission also lays down that the Sectoral Long Term plans must be such as to call for the *minimum volume of development outlay as against the given physical targets.*

Step 2. The Ministries accordingly prepare their long-term plans and submit those to the Planning Commission. Let the technological-organisational choices involved be $T_1^1, T_2^1, \dots, T_N^1$.

Step 3. The Planning Commission finds that the different Sectoral Long-term Plans submitted by the Ministries cannot simply be put together, as they lack Horizontal Harmony. Keeping the technological-organisational combinations T_j^1 unchanged, the Planning Commission adjusts the levels of physical output set as targets for the different sectors and suitably alters the sectoral long-term plans to correspond to those changed targets until the different long-term plans satisfy all the balance relations. The sectoral plans, as now adjusted, may be designated by $P_1^1, P_2^1, \dots, P_n^1$ and together constitute a perspective plan, say P^1 . Let the total outlay and total increment in resources be D^1 and r^1 respectively.

Step 4. The Planning Commission gives out the figure $\theta^1 = \frac{r^1}{D^1}$

to the Ministry concerned with sector j and asks it to find out whether it can think of a technological-organisational Combination T_j^2 for sector j such that it will involve an increase (or decrease) of outlay of $\Delta^2 D_j^1$ in sector j and an increase (or decrease) of the resources from that sector of $\Delta^2 r^1$ such that

$$\frac{\Delta^2 r_j^1}{\Delta^2 D_j^1} > \theta^1 \text{ (or } < \theta^1 \text{)}.$$

If so, the Ministry will be asked to change the Sectoral Plan P^1 by raising its outlay by a small extent* and using T_j^2 instead of T_j^1 for the technological-organisational Combination.

Step 5. The Planning Commission will find that the revised long-term plans submitted by the ministries too are not such that they can be simply put together, for they are once more not mutually consistent. Keeping the combinations T_j^2 in tact, the Planning Commission will have as before to adjust the output levels and arrive at mutually consistent Sectoral Long-terms Plans $P_1^2, P_2^2, \dots, P_N^2$ which will together constitute a second Perspective Plan P^2 .

Step 6. The Planning Commission will once more calculate

$$\theta^2 = \frac{r^2}{D^2} \text{ and give out its value to the}$$

Ministries with similar instructions as in *Step 4.* The process will stop at a stage n at which for no sector j will be possible for the concerned Ministry to effect a change involving a further outlay of $\Delta^{n+1} D_j^n$ and giving rise to an increment in resources from that sectors, $\Delta^{n+1} r_j^n$ such that

$$\frac{\Delta^{n+1} r_j^n}{\Delta^{n+1} D_j^n} > \theta^n. \text{ The Optimum}$$

Perspective Plan then will be the one that uses the technological-

* Every successive Perspective Plan will have a higher total outlay and therefore also every successive sectoral Long-term Plan for any given sector.

organisation combinations $T_1^m, T_2^m, \dots, T_N^m$. (It is of course not necessary that T_j^m must necessarily be different from T_j^{m-1}, T_j^{m-2} etc. for all j . It is possible that the optimum Combination for a particular sector j is reached at an earlier stage than n).

10. The iteration process would coverage quicker if it is modified in the following way. At stage s instead of changing over to any combination T_j^s ($j = 1, 2, \dots, N$)

$$\text{such that } \frac{\Delta^{s+1} r_j^s}{\Delta^{s+1} D_j^s} > \theta^s, \text{ the in-}$$

structions may be that the change-over must be to a Combination T_j^s such that $\Delta^{s+1} D_j^s$ is a maximum subject to the condition of

$$\frac{\Delta^{s+1} r_j^s}{\Delta^{s+1} D_j^s} > \theta^s; \text{ that is to say,}$$

the outlay in sector j is to be increased (by keeping the output level constant but varying techniques and organisation) as long as $\frac{\Delta^{s+1} r_j^s}{\Delta^{s+1} D_j^s}$ remains greater than

θ^s . If this modified rule is followed then the iteration process will work in a zigzag fashion; that is to say, for each sector, a step consisting in increasing the outlay will be followed by a step consisting in reducing it. This is obvious, for let T_j^{s-1}, T_j^s and T_j^{s+1} be the combinations chosen for sector j in the $(s-1)$ th, s th and $(s+1)$ th steps. We have only to prove that if $D_j^s > D_j^{s-1}$ then D_j^{s+1} must be $< D_j^s$. Suppose that this is not true, i.e., let $D_j^{s+1} > D_j^s > D_j^{s-1}$.

$$\text{Now we must have } \frac{\Delta^{n+1} r_j^n}{\Delta^{n+1} D_j^n} > \theta^n$$

$$\text{and } \frac{\Delta^n r_j^{n-1}}{\Delta^n D_j^{n-1}} > \theta^{n-1}. \text{ But as}$$

$$\theta^n > \theta^{n-1} \frac{\Delta^{n+1} r_j^n}{\Delta^{n+1} D_j^n} > \theta^{n-1} \text{ and}$$

$$\text{therefore } \frac{\Delta^{n+1} r_j^n}{\Delta^{n+1} D_j^n} > \theta^{n-1}. \text{ That}$$

is to say, according to our modified rules, one should have moved from T_j^{n-1} straight to T_j^{n+1} , skipping T_j^n .

11. While for composite sectors with a multiplicity of alternative

techniques and organisational arrangements, the procedure at the ministerial level cannot but be of groping among possible alternative Combinations, the problem can be conceivably easier for homogeneous sectors where it is possible to see at one glance the alternative combinations possible for the sectors. We shall consider two simple situations to illustrate the point. Let the alternative combinations applicable to sectors j be arranged in the increasing order of the magnitude of outlay involved for a given volume of output in that sector. Let the sequence be designated by $1T_j, 2T_j, 3T_j, \dots$ etc. The corresponding outlays and increments in contribution to plan resources may be designated by $1D_j, 2D_j, 3D_j, \dots$ etc. and $1r_j, 2r_j, 3r_j, \dots$ etc. respectively. $sD_j <_{s+1}D_j$ for all s . We shall also assume that $r_j <_{s+1}r_j$. (This can always be ensured by dropping from consideration any Combinations that do not satisfy the relation).

Situation 1. $\frac{s+1r_j - r_j}{s+1D_j - sD_j}$ is an increasing function of s . The move at stage s is to choose either T_j (max.) or T_j (min.) (where they stand for the combinations involving the maximum and minimum of outlay) depending on whether—
 $\frac{r_j \text{ (max.)} - r_j \text{ (min.)}}{D_j \text{ (max.)} - D_j \text{ (min.)}}$ is greater than or less than θ^* .

Situation 2. $\frac{s+1r_j - r_j}{s+1D_j - sD_j}$ is a decreasing function of s . The move at stage s is to choose uT_j where u is such that—

$$\frac{u+1r_j - u^r_j}{u+1D_j - uD_j} < \theta^* \quad \text{and}$$

$$\frac{u^r_j - u-1r_j}{uD_j - u-1D_j} > \theta^*.$$

(If one imagines r_j and D_j to be connected by a function f with a negative second derivative all along its range, the optimum lies at the point where the first derivative equals θ^*).

It is unlikely that the Combinations for any sectors would be such

as to satisfy either of the two conditions assumed in the two above situations. But it would always be possible to partition the sequence $1T_j, 2T_j, 3T_j, \dots$ into subsequences such that within each subsequence $\frac{s+1r_j - r_j}{s+1D_j - sD_j}$ is either increasing or decreasing. It is then possible to know, from the above, the right moves at stage n , for each such subsequence. One can thus arrive at a number of 'optimum points,' one for each subsequence. One can treat these alternative 'optimum points' exactly in the same way as before, and ultimately arrive at the optimum move with respect to the entire sequence.

Why Maximise Surplus ?

12. Uptil now we have proceeded in our discussions in terms of the general term "Resources for Planning" from sector j and assumed that the amount varies with the technological-organisational combination adopted for sector j . In many a discussion of the problem of technological choice it is assumed for simplicity that the plan resources consist entirely of "Surpluses" in the Marxian sense. In the context of Indian planning however such an assumption might be quite misleading. For, the domestic resources for the Indian Five Year Plans are derived in their larger part from sources other than the "Surpluses." A large part of the public sector outlay is financed by tax and loan receipts and only one part of such receipts impinge on the Surpluses, the remaining part being fed by wage and salary income and the income of the self-employed. Investment in the private sector also is only to a limited extent financed by the Surpluses; for India being a country predominantly of unorganised enterprises in which no surpluses are generated, investment in the private sector has to be financed to a large extent, once more, by wage and salary income and the income of the self-employed. Thus, if it is desired to maximise the total availability of resources

for planning, it may not at all be the right thing, under the existing conditions in India, to maximise the surplus generated in the whole society. As a matter of fact, it is possible that the maximum volume of surplus is achievable only at the expense keeping the level of income well below the possible maximum. This in turn might actually mean a volume of resources for planning below the maximum possible.

13. We shall therefore not equate resources to surplus but use a more adequate relation. We shall write

$$R^i = \sum_{j=1}^N y_j^i \{ \beta_j^i + (1 - \beta_j^i) f_j^i \} - G$$

where β_j^i is the share of income generated in sector j going to corporate bodies in the form of corporate profit and $1 - f_j^i$ is the share of non-corporate income in sector j that gets consumed on private account. Both β_j^i and f_j^i depend on the structure of sector j as well as the financial policies pursued by the authorities with respect to the sector. We cover both these aspects of the economy of a sector by the term "Organisation" and thus make the values of β_j^i and f_j^i dependent on the Combination T_j^i chosen. y_j^i is the income generated in Sector j and $y_j^i \beta_j^i$ the part that accrues as profit to corporate organisations. We are assuming that the whole of this part is either directly invested or contributed to Government for the latter's investment and consumption. What part of it reaches the two final destinations of investment and government consumption through the shareholders of the corporate bodies and what part directly, in the form of taxes paid by or loan contributions from the corporate bodies themselves, is immaterial. All that is necessary to assume is that no part of the profit earned by corporate organisations is consumed on private account. This is an assumption similar to, but much weaker than, that of the entire surplus being invested.

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