ROLE OF PLANNING TECHNIQUES IN A SOCIALIST ECONOMY, WITH SPECIAL REFERENCE TO THE USSR

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF PHILOSOPHY
OF THE JAWAHARLAL NEHRU UNIVERSITY
SCHOOL OF INTERNATIONAL STUDIES

NEW DELHI-110067
1980

C O N T E N T S

PREFACE

The socialist economic system has come of age. Its ability to generate sustained growth with stability and without unemployment, has been proved beyond doubt. Its success cannot be wished away. Nor can it be contended that the Smithian invisible hand, or the market, is the best guide to an efficient allocation of resources. Success, especially of the Soviet experience has established 'Planning' as a more than an able successor to the now discredited laissez-faire market mechanism. Indeed, even the advanced capitalist countries, now talk of plans and planned economic development.

Economists from the Soviet Union and other socialist countries contend that an efficient allocation of resources is possible only under social ownership of means of production. It is no accident that linear programming, the most widely used technique for ensuring the efficient allocation of resources was discovered not in an atomistic, competitive, economy, but by a mathematician in a socialist economy in order to solve a planning problem. Even the technique associated with the name of Wassily Leontief viz. input-output had its origins in the work done by Soviet economists in the 1920's.

This work makes a critical analysis of planning techniques as they are applied to ensure consistency and optimality in current plans in the Soviet Union. The discussion is strictly confined to material-balances, the input-output and linear programming.

The study is with reference to the Soviet economy not only because Soviet economy was the first laboratory, as it were, where these techniques emerged and could be tested, but also because the long life-span of the Soviet economic experience provides the historical setting wherein what can be called the new and the old techniques can be juxtaposed to facilitate a more meaningful analysis.

The analysis suffers from the limitations of any study based wholly on secondary sources. Language-problems have prevented the use of primary sources.

I take this opportunity to thank Dr. Arvind Vyas, my supervisor, who aroused my interest in the topic and gave me invaluable guidance at all stages of the work, without which this dissertation would not have been possible. I would also like to thank Balbir Butola and Ashwini Sharma for their useful assistance at various stages of the work. Lastly, I am grateful to the staff of the Central Library, Jawaharlal Nehru University, for their assistance in procuring the required material.

NEW DELHI
JUNE 16, 1980

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CHAPTER I

THE PROBLEM : AN HISTORICAL SURVEY

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> " The system of economic planning in the USSR did not spring full-grown from the head of Lenin, as some people seem to have assumed. It had a history of growth and change over two decades, at some stages of tortuous growth; and certain historical prerequisites were needed before economic planning could be anything more than partial and tentative - a fitful hand upon the reins rather than a curbing and steering of the system "
>
> (M. Dobb, Soviet Economic Development Since 1917, pp.337)

In the early years of the Soviet regime, stretching from war communism to the New Economic Policy, planning was more of a doctrinal slogan than an economic force. Even though a central planning machinery had been created, its efforts could not crystallise in the form of a unitary and unified plan for the economy as a whole because "neither the objective situation confronting it nor its own subjective fitness for the task,"[1] had matured to the extent necessary for a successful planning venture.

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1. M. Dobb, Soviet Economic Development Since 1917, (London, 1966), pp.337.

Planning had its beginning in 1921 in the form of the well known GOELRO plan for the electrification of RSFSR. GOELRO was the first perspective plan of the first socialist state, and the methods of planning used in it were as yet crude and primitive. Howdver, the theoretical underpinnings were clear. These were based on the reproduction schemes used by Marx in his analysis of the capitalist mode of production. Lenin believed that the reproduction schemes retained a certain significance for the conditions of socialism with regard to the properties in Departments I and II and accumulation. The idea derived from the Marxian theory of reproduction was that of the proportional development of the basic departments of production i.e. I and II. GOELRO plan emphasized this notion and the first balance calculations of a general planned character were presented in the plan. A broad use was made in the plan of the balance method for determining the volume of production and construction and the need for supplies and manpower. The plan contained tables of the balance of fuel and power. The material and financial balances of electrification in the plan received an affirmative assessment from Lenin.

The concept of the balanced development of the national economy was to form the basis on which the subsequent planning techniques were to develop. The requirements of a planned economy during these early years of socialist construction generated a variety of research projects on economic balances of the balance-sheet type. Above all a start was made in drawing up the natural quantitative balances of grain products and fuel.

In a decree dated July 21, 1924, the Council of labor and defence ordered the Central Statistical Administration (TsSU) to compile a balance of the national economy for 1923-24. The TsSU came out with the first ever balance sheet of the national economy in 1925. This was a step forward in many respects. Particularly noteworthy was the attempt to produce figures covering not only production but also distribution of the social product so as to give a general picture of the reproduction process in the form of a tableau economique. In 1926 the same board prepared material balances covering 28 agricultural, 2 forestry and 8 manufactured products widely consumed in the country. "The most valuable feature of this work" observed by Nemchinov "was the tables showing capital, the production-distribution balance of social product, national income and a chess board balance-sheet of productive consumption."[2] The production and use of the social product balance was broken down by branches and products. The end products, raw materials and material, fuel and equipment used in production were shown in separate lines for all branches of production. The chessboard table showed consumption of industrial products where the intra-industrial turnover of individual branches of industry was given revealing the interdependence and the chain connexion between the individual branches of the economy.

In 1928 an article appeared by M. Barengolts under the title 'The Capacity of the Soviet Industrial Markets' containing a chessboard balance sheet for 11 branches of Soviet industry over the three years 1922-3, 1923-4, and 1924-5. Something new and significant here was Barengolt's clear formulation of the concept of technical coefficients.

The 1925-26 control figures used individual grain forage balances in compiling the overall balance. In the control figures for 1926-27 it was noted that the system of balance calculations should be viewed as the basic method of compiling and substantiating the control figures.

The materials on the first five-year plan contained long-range balance calculations, in particular,

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2. V.S. Nemchinov, "The Use of Mathematical Methods in Economics" in Alec Nove (ed.), The Use of Mathematics in Economics (English Edition) (London, 1964), p.3.

the agricultural, balance of labor from 1929-30 to 1930-31, the cumulative balance of the fuel industry etc. Balance calculations were used more and more in the elaboration of national economic plans and in statistical works. The following material balances were compiled : grain-forage, fuel, electric power, metals, construction materials etc. Balances of finance, manpower and fixed capital were also prepared.

Following the publication of the works of the TsSU numerous articles devoted to the theory and methods of compiling the balance of the USSR national economy appeared in the periodical literature. In 1927 S.G. Strumilin in an article on the methodology of the balance of the national economy emphasized the organic relationship between the balance of the national economy and that of individual branches. He stated "from this point of view the balance of the national economy cannot be structurally different from the partial economic balances on which it is based."[3] In the subsequent period upto the end of the 1930's, there was a lively discussion in the press on the problems pertaining to the development of ideas on

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3. Quoted in A. Petrov, ~~xxx~~ "The Balance of the National Economy as a Scientific basis and method of Analysis of Socialist Reproduction", Problems of Economics, Vol.XX, No.1, p.73.

the balance of the national economy. It was during this period that the method of material balances was perfected and it emerged as the leading technique of planning and as a means for establishing the inter-economic and inter-branch links in the economy.

The method of material balances was derived from the actual knowledge of the requirements of the productive process. In this sense they were based on the technical coefficients of production and not on inductive statistical generalisation.[4] What was more important was that the method had focused the enquiry and discussion to the detailed inter-relationships and needs of particular production processes, and had highlighted the notion of the structural interdependence of the economy. The material balance methods together with the pioneer nature of the work done in the national balance sheet and Barengolts work mentioned above, provided revealing insight into the structural interdependence of the economy based on definite input-output relationships.

Thus the background for the development of the input-output analysis as known today had already been prepared. What is indeed surprising is that in subsequent years a sufficient advance could not be made on these promising beginnings. "No attempt was made (so far as one is aware) to generalise the system of input-output

4. Dobb, n.1, p.356.

relationships or even to contemplate mathematical techniques for doing so in the way that this was done outside the country by Wassily Leontief."[5]

One important reason why theoretical refinement of the balance method was not followed up, mentioned by Dobb,[6] was the disfavour into which this type of analysis fell during the early 30's as a by-product of polemic against the Gosplan economists of the Groman-Bazarov School. "Such attempts were apt to be denounced as 'mathematical formalism', and as 'bourgeois formalism' to boot; and in a period ruled by dogmatism, especially in social sciences, such as was to develop as the decade advanced, this kind of slur, once pronounced, was sufficient to inhibit initiative in this direction and at any rate to preclude it in published form."[7] On one occassion, Kuibyshev the then head of Gosplan had condemned what he called "the statistical-arithmetical deviation in planning", and in particular the use in planning of "abstract models".[8]

On an earlier occassion Stalin himself had decried the TsSU balance-sheet as a mere "juggling with figures".[9]

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5. *Ibid.*, pp.357.
6. *Ibid.*, p.360
7. *Ibid.*, p.360
8. Cited *Ibid.*, p.360
9. Stalin, *Problems of Leninism*, (Peking, 1976), pp.476.

Stalin was right to the extent that the objective conditions, at a time when agriculture was predominated by non-socialist relations of production, were not ripe for the use of such methods. But what certainly should have been acknowledged wat that in the subjective sphere i.e. in the methodology of planning these works were of a path-breaking character, and they should have been encouraged, their inapplicability at that particular point of time notwithstanding.

In the second half of the 30's Strumilin tried to revive the discussion about a synthetic 'balance of the national economy' by developing some kind of analysis on the basis of Marx's schema. The discussion could not go beyond the stage of classification, when it was dismissed by the authorities as unsatisfactory and was, to use a cliche, nipped in the bud. This attempt was to be the last one as long as Stalin reigned.

The only method to be followed faithfully, as mentioned above, was the method of material balances, However, if one looks into the process of industrialisation and the conditions in which it was carried out, the neglect of various methods appears quite explicable.

Economic planning, like the market, is an economic force which supervises production and distribution of goods.

Planning techniques are required to coordinate the activities of various branches, industries and enterprises in accordance with the aims and objectives laid down in the national economic plan. The latter are dictated by the level of development of the productive forces and the relations of production, and, of course, the political objectives. The planning techniques, in terms of their functional effectivity at any point of time, it follows, should correspond to the level of development of both the forces and the relations of production, and should, indeed, advance as the latter advance.

The method of material balances survived and developed in 1930's, at a time when dominant contradiction in the Soviet society was the existence of socialist relations of production with a very low level of development of productive forces. The major task before the Soviet planners was a rapid development of productive forces and the rapid attainment of the size and structure of an advanced economy. The priorities were the development of basic industrial commodities (metals, fuels and chemicals) electric power and machinery. All the efforts were directed at increasing the stock of productive resources, to direct these resources into the high priority sectors and thus to alter drastically the structure of the economy.

The constraints imposed internally by the above priorities and the hostile external situation, coupled with the onset of the fascist threat and the subsequent war made a centralized administrative type of planning imperative. In a centrally administered economy, with a few priority sectors, and with a not-so-complex system of inter-industry relationships, the method of material balances served the needs of the planners quite adequately. The method was relevant when the dominant objective was the construction not of a perfectly consistent or an optimal plan involving the most efficient use of resources, but of a plan which was realisable in terms of a few priorities. There was little scope in the existing situation of scanning alternative processes in search of an optimal or the most consistent plan, and consequently the techniques for doing so viz. input-output analysis or linear programming which were to be in vogue later, received scant attention. Alec Nove has aptly described the situation as being one in which "strictly economic criteria have only very limited application in the midst of crash programmes designed to build up heavy industry in the shortest possible period of time. This type of operation carried out by methods reminiscent of a war economy is genuinely hard to reconcile with an economic theory in which choices are related to economic effectiveness, and particularly so because the typical administrative arrangements of a war economy - allocation of materials, priorities, strict price controls and so on - distort the measurement of economic advantage and of costs of alternatives."[10]

By the mid-50's, after the post-war reconstruction effort, the situation, however, became ~~because~~ radically different, and put mounting strains on the system of centralised planning, revealing its weaknesses. Three major differences in the new situation were easily identifiable. Firstly, the structure of the Soviet economy had become increasingly complex and huge, and with the multiplication of the inter-relationships it produced and the increased sophistication of some of the latest technology, made planning from the centre in the old ways increasingly difficult. The number of industries, enterprises and products to be managed had multiplied enormously. Secondly the days of extensive growth when abundant labour reserves in the countryside could be drawn upon were over. Both skilled and unskilled labour was now scarce and the economy had entered a period of intensive growth which could now come mainly through rapid increases in labour productivity and more efficient utilization of existing resources.

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10. Alec Nove, (ed), The Use of Mathematics in Economics, (English edition), Introduction, p.x.

Finally, the days of priority for department I industries were over. An increasing attention had now to be devoted to consumer's goods industries. As Dobb says "the previous priority scale was superseded; indeed, the previous clear-cut distinction between priority sectors and non-priority began to break down and to become increasingly blurred," and "the achievement of a 'balanced' production-programme began to replace a simple priority - rating of tasks as a policy-objective." [11]

The overall focus was now shifting away from macro-structural change to improving micro-efficiency. The strengths of the centralized system lay in its power to mass resources on a few clear priorities. Similarly the method of material balances, which had now become primitive in relation to the advanced level of the productive forces, was now proving inadequate to discharge the function of coordinating the activities of all the sectors of a complex economic mechanism and to meet the demands imposed by the necessity of a balanced development of the two departments (in the Marxian sense) of the economy. The traditional methods of calculation, similarly, were not adequately

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11. M. Dobb, <u>Socialist Planning : Some Problems</u>, (London 1970,) pp.31.

stimulating an efficient utilisation of economic resources and the requisite increases in labour-productivity. In brief, a new contradiction had now emerged in the Soviet Union - the traditional methods of planning and management were becoming a fetter on economic efficiency.

Discussion around the need for decentralization of the planning mechanism in terms of giving more freedom and initiative to the enterprise and the use of more efficient mathematical tools in planning began soon after Stalin's death. But it was only in the 60's that the movement for reforms gained momentum especially after Liberman's work in 1962 entitled 'The Plan, Profits and Bonuses'. The breakthrough came in 1965 when the economic reform was announced. What came to be called Libermanism emphasized methods to remove deficiencies in the plan implementation. What it ignored was the task of more effective plan construction. It is here that the mathematical wing of the reform movement comes into the picture. This wing concerned itself both with plan construction as well as plan implementation. This wing gained strength from the 20th Congress onwards. Their discussions covered a broad front, from highly abstract questions in pure mathematics to problems regarding the application of mathematics to economics. Among the latter, attention has been given to information systems, and the use of input-output and linear and non-linear programming for the construction and operation of internally consistent and optimal short-term and long-term plans, for investment planning and for materials supply planning.

Here it would be necessary to mention the name of Nemchinov who from 1957 onwards repeatedly advocated the use of quantitative methods of analysis of economic phenomena. Using the 1950 British input-output table as a basis he began popularising, the idea of input-output in the USSR. Nemchinov demonstrated that the idea of input-output table derived from the work done by the Russian economists in 1920's (as mentioned above) and had its roots in Marxist theory. He was able to persuade TsSU to compile an input-output table for the USSR for 1959 which was published in 1961. Subsequently more such tables were compiled and at Nemchinov's initiative the analysis was extended to the regional level also. Nemchinov's efforts, ably supported by economists like Novozhilov, Vainshtein and Konius lead to the establishment of the Central Economic Mathematical Institute (TSEMI) and played a prominent role in the development of the economic-mathematical direction within Soviet economic science after the 20th Congress.[12]

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12. See M. Ellman, Soviet Planning Today, (Cambridge, 1971), pp.2-3.

In 1959 Kantorovich's famous work "Economic Calculation and the best use of resources" edited and with a preface by Nemchinov was published. The book, which explained in a simple fashion the relevance of linear programming for economic planning in USSR was greeted by hostile reviews. A vigorous debate had now started with the orthodox political economists in confrontation with the mathematical economists. The latter, initially, were in a small minority, but they gradually gained strength and were able to evoke a favourable attitude from official quarters. In 1965 the Lenin prize was awarded to Kantorovich, Novozhilov and Nemchinov. In the 1966 debate on optimal planning TSEMI put forward far reaching proposals for reforming the economic mechanism and challenged the position of the political economy. TSEMI claimed that the application of mathematical methods and com puters would enable the problems of the planning system to be overcome and substantially increase the efficiency of the system.

The debate between the political-economists and the 'economic cybeneticians' revolved around four basic issues.[13] Firstly, the mathematical theory of prices, in which prices are a set of numbers capable of providing optimal solutions was treated by the political economists as anti-Marxist and as contrary to the labor theory of value. Kantorovich and

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13. See *Ibid.*, p.4.

Novozhilov were accused of resorting to bourgeois marginalism in the place of value in the Marxist sense. Even some of the mathematical economists such as Gerchuk[14] have criticised Kantorovich and his followers of nurturing exaggerated ideas about the applicability of linear programming.

Secondly, the concept advanced by optimal planners, regarding national economic planning as an extremal problem choosing a set of numbers, the intensities at which activities will be operated, was unacceptable to the political economists, who argued that planning cannot be identified with the solution of some mathematical problem, but is more complex having social, political and technological aspects which require conscious decisions by planners. The presentation of national economic planning as an extremal problem, by the selection of an optimal intensity factor, which, given the technology matrix, maximises some objective function, seemed at first sight very odd to many Soviet economists. The notion was criticised by Nemchinov in his preface to Kantorovich's book. The concept has subsequently become the central pillar of the theory of an optimally functioning economic system. A relevant criticism against cyberneticians is that it concentrates on the rational organisation of the productive forces and neglects the need to develop the productive relations.

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14. See *Ibid.*, p.6.

The third problem arose regarding the intellectual and organisational question of the relationship between the newly emerging economic cybernetics and Marxist-Leninist political economy. The cyberneticians like Federenko argued for the replacement of the descriptive approach i.e. political economy by a constructive one i.e. the theory of optimal planning.[15] The political economists on the other hand have asserted that any theory for improving economic practice has to be subordinated to the leading role of the Marxist-Leninist political economy. A settlement has now been reached, in this sphere, along the lines suggested by the political economists. The optimal theorists have abandoned their earlier critical attitude towards political economy and have recognised that only Marxist-Leninist political economy can form the theoretical basis of the economic policy of a socialist economy.

Finally, an issue vigorously debated has been the role of the traditional planning methods. The optimal planners have dismissed the traditional methods of planning as being non-scientific and subjective. According to them the only scientific conception is the one of optimal planning. On the other hand economists like Mikhail Bor and Bachurin have attacked the optimal theorists for implying that planning in Soviet Union has been subjective and non-scientific, and have dismissed the concept of optimal planning as being similar to that of 'market socialism'.[16]

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15. See *Ibid.*, p.8   16. *Ibid.*, p.12.

Nevertheless, by the 1970's the mathematical economists had vastly improved their standing. Today a consensus seems to have been reached that the use of quantitative methods is necessary for an efficient and successful planning mechanism. Conditions have been created for the development of the economic-mathematical direction in Soviet economic science. This development is not confined to the theoretical plane and lecture rooms alone - increasing use is being made of computers and mathematical models as input-output tables, and linear programming etc. Two questions which need to be investigated at this juncture are, (a) to what extent can the application of mathematical methods help raise the efficiency of economic planning and management? and (b) what is the nature of the relationship between mathematical economics and the political economy of socialism?

The two subsequent chapters would concentrate on issues raised by the first question. Chapter two would evaluate the methods of material balances and input-output as techniques to solve the problem of plan consistency. Chapter three would focus on linear programming and its applications in the quest for optimization and point out its various limitations in this context. Chapter four would be the concluding one, summing up the analysis pursued in the two preceding chapters, and very briefly deal with the second question we raised regarding problems relating to the political economy of socialism.

CHAPTER II

PLANNING TECHNIQUES AND THE PROBLEM OF CONSISTENCY IN CURRENT PLANNING

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I

The operational plan in Soviet planning practice is the annual plan (with its quarterly and monthly subdivisions). As compared to the five-year plan, data in the annual plan is much less aggregated, since it forms the basis of direct commands to the enterprises in the economy. Within the framework and guidelines provided by the national plan, a 'tekhpromfinplan' is worked out for every enterprise, which describes in detail its activity during the planned period. A consistent plan requires that for the planned period the following two conditions be satisfied :

1) At the level of the enterprise, the planned output should be feasible with the planned inputs i.e. no enterprise should receive an impossible plan.

2) At the level of the economy as a whole, the planned requirements for each commodity should not exceed the availability of that commodity.

Violation of condition one, will result in some enterprises not being able to fulfill their plans, this in turn adversely affecting the enterprises which planned to use the good which was not produced as an input or the final consumers for whom the good was being produced. The violation of the second condition, would in a similar manner, lead to shortages or glut of some commodities. The consequences would be splitting up of the economy into a priority sector whose needs are met and a non-priority sector whose needs are not met.

II

The Organisational Structure and the Process of Plan Formulation

The enterprise tekhpromfinplan is worked out through an iterative mechanism, with the information flowing between the Gosplan, the ministries and the enterprises. The process of annual plan construction begins six to eight months before the beginning of the plan year with an intensive study of the statistical picture of the economy with the aid of this information and in relation to their long-term and short-term policies, the political leaders formulate and communicate their basic priorities for the forthcoming year to the central planners.

Subsequently the Gosplan, taking into account the latest production figures as well as forecasts of productive capacity and labor force, prepares preliminary balances of essential products, and on the basis of these hands down tentative targets or control figures to the various ministries. Each ministry, at the same time is receiving suggestions from its subordinate enterprises about the latter's needs and productive possibilities. The ministries then modify the control figures supplied by the Gosplan in the light of the suggestions received from the enterprises, and then subdivide them among their chief industrial administrations called _glavki_. Each _glavki_ in turn sends down the requisite targets to its subordinate enterprises.

The enterprises estimate their output possibilities in terms of a somewhat more detailed nomenclature, and, using input coefficients (norms) established for them at different levels of the hierarchy, calculate their input needs. These requirements are then submitted in the form of indents to the respective *glavki*, which in turn forward it to the procurement organisation of the ministry. At all levels of each application is thoroughly checked and the approved version is then consolidated with other applications. Specific care is taken to see that the material requirements are in conformity with the latest available output figures and the established input coefficients.

The ministries, now with the help of their *glavki* and marketing organisations draft more detailed production plans, remodifying and complementing the control figures they had previously dispersed. The plan is now returned to the Gosplan, whose job it is now to work out the internal balance or the consistency of the plan. With this one round of iteration is complete. The specialised industrial departments of the Gosplan prepare material balances for the centrally allocated products on the basis of these latest production and procurement data. These balances record the planned demands for and sources of supply of each of the requisite products. The balances are then closed with a concurrent adjustment of demand and supply achieved in all the balances. But before this adjustment can be realized, it is often necessary to go through many more iterations - on each occasion the relevant department of Gosplan or the ministry being expected to figure out the input requirements of subordinate enterprises from the output targets in the latest version of the yearly plan. It is only through this iterative procedure that all balances can be achieved simultaneously. The process of plan construction, however, does not end here. The output targets from the confirmed plan addressed to ministries, are subdivided and passed down to the enterprises which now calculate their input needs at a very detailed level. The detailed input requirements come up the ministerial hierarchies and are sent to central agencies where again material balances are drawn up, this time for many more commodities, whose quantitative dimensions, however, are supposed to be just disaggregations of the data in the state plan. Producing-enterprise to consuming enterprise ties are established and formal contracts between them are signed, thus ending the process of plan construction.

A distinction of importance is between the centrally and non-centrally distributed products. The Gosplan and Gossnab (the central organ for the planning of supply) prepare balances for the centrally distributed products. Balances for the decentrally distributed commodities which cover the detailed disaggregated requirements of the

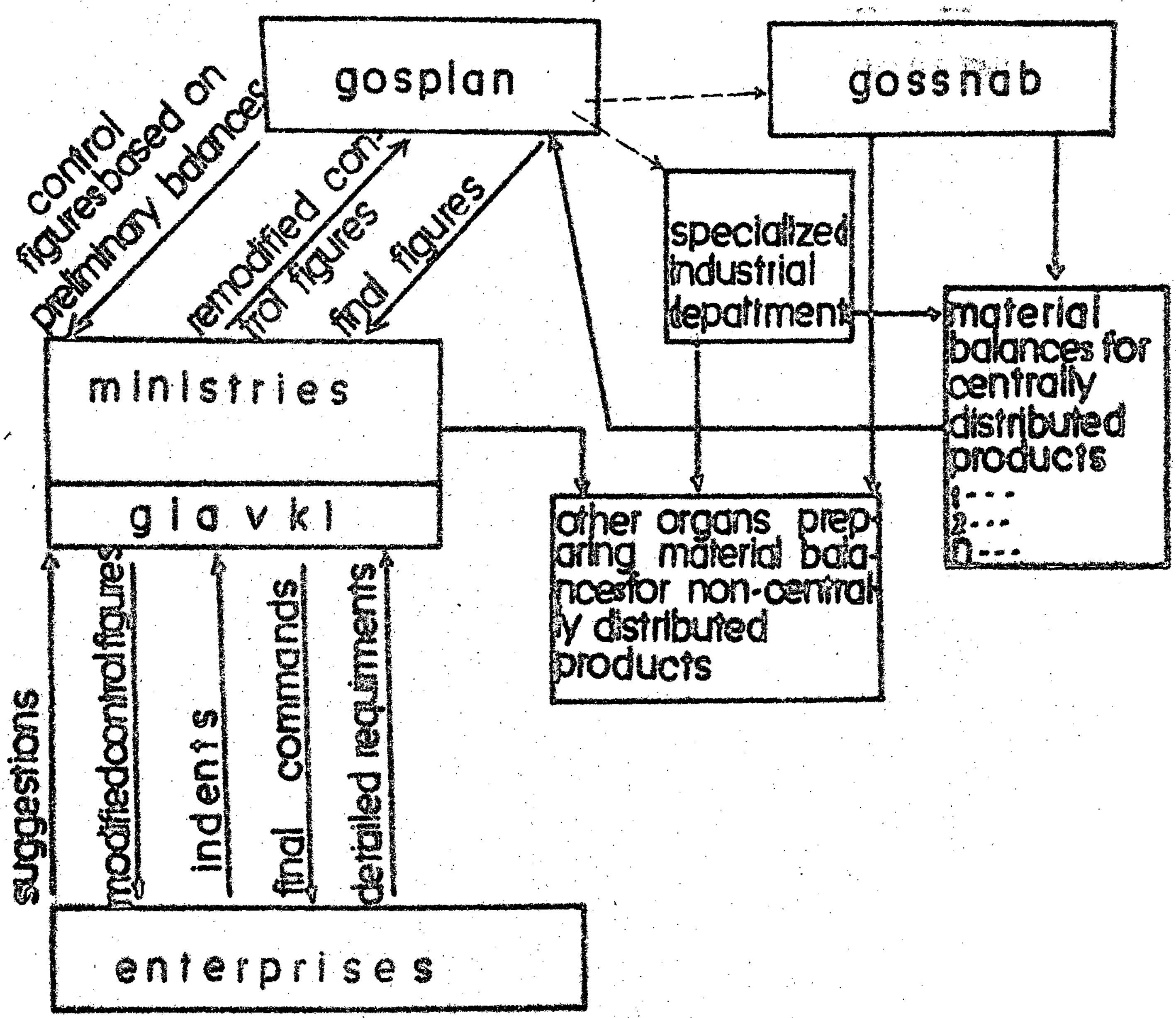

fig I the organisational structure: plan formulation through iteration enterprises are prepared by various organs attached to GOSSNAB, ministries etc. The organisational structure and the process of plan formulation is shown in the diagram. (See figure 1).

III

Plan Consistency with Material Balances

A material balance for a product accounts for all the sources and uses of a product. It is simply a supply and demand equation for each product, mathematically which can be written as :[1]

$$x_i = \sum_{j=1}^{m} a_{ij} x_j + y_i \qquad \begin{array}{l} i = 1 \text{ ——— } m. \\ j = 1 \text{ ——— } m. \end{array}$$

where x_i = output of the i^{th} product

x_j = output of the j^{th} product

a_{ij} = input coefficient, showing input of product i per unit of product j

y_i = amount of the i^{th} product required for final demand.

If the economy is producing m products, then consistency, as defined by us in section one of this chapter, would require that a general equilibrium of all the m balances is obtained. This would involve taking into account all the interdependencies between them, which means mathematically speaking treating them as a system of

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1. See J. Kornai, Mathematical Planning of Structural Decisions, (Amsterdam, 1965), p.5

m simultaneous equations and considering the conditions for the solution of the whole system.[2] Such a solution, however, requires that the following conditions be satisfied :

1) That balances are prepared for all the products, showing all the sources and uses of the product i.e. the balances are universal,

2) The balances cover the entire output of the good i.e. they are complete,

3) All the balances form an integrated, interlocking set,

4) Real production processes conform to the technological assumptions inherent in the usage of fixed input norms, the a_{ij}'s.

The method of material balances as used in socialist economies, does not satisfy any of these four conditions, and fails to ensure compilation of consistent plans.

The main source of all problems is the vast mass of computation involving millions of equations if balances are prepared for all the products covering all the enterprises producing or using a particular product.[3] It is primarily the necessity to reduce the number of equations, and the number of enterprises an equation covers, which directly leads to the violation of the first three conditions, and is to some extent, though not wholly, responsible for the

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2. See M. Dobb, Soviet Economic Development Since 1917, pp.357-8.

3. The sheer size of the problem can be gauged from the fact that currently there are over 20,000,000 products in the USSR. It has been assessed that even if all the labour force available in the USSR was to do the job, it would be unable to solve all the equations in the required time.

violation of the fourth condition also. The equations of the material balance system are reduced in two ways. Firstly, balances are not prepared for all the products — they are only prepared for products deemed as more important in a given situation. Thus material balances are compiled for far fewer commodities than are produced in the economy, and do not cover the whole of social production.

Secondly, the rows are further reduced by aggregating various products under the heading of one product title, leading to the exclusion of some more products from the balance calculations. For example, the balance of pumps aggregates all the various types of pumps in one balance, the balance for motor vehicle industry aggregates jeeps, lorries, cars, tankers, etc. all kinds of vehicle together.

The result of all this is that the balances do not form a universal set and as the balance system gets less and less universal the inconsistency of the results gets more and more magnified. The process of aggregation adds a further dimension to the problem. The aggregation of heterogenous goods into artificial homogeneous goods can lead to three types of errors[4]:

(i) The whole process of aggregation of input requirements for many goods into requirements for the aggregate good and then disaggregating the production plan for the aggregate homogeneous good into plans

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4. M. Ellman, Soviet Planning Today, (Cambridge, 1971), p.95.

for the heterogeneous goods required, may distort the information regarding the relative quantities in which the goods are required, leading to formulation of inconsistent plans.

(ii) Enterprises instructed to maximise the production of the aggregate good may produce an output mix which is wide off the mix desired by the consumers, leading to non-fulfillment of plans of the consuming enterprises and creating marketing problems for a certain range of complementary inputs.

(iii) The planners may compile inconsistent plans because the method of aggregation used may be inconsistent. Aggregation is said to be consistent when the use of information more detailed than that contained in the aggregates would make no difference to the results of the calculations.

If the aggregated products in question are close substitutes then the discrepancies introduced by aggregation may not be as serious as they would be when there are gaps in the chain of substitution. For instance, in the electricity supply industry the process of aggregation and disaggregation does not cause inconsistent plans. The problem arises in industries where output is heterogeneous, as in the textile industry.

Aggregation amounts to having two implicit assumptions in the plan[5] : First, the relative outputs of the various products which make up the industry will remain unaltered. Second, all the products have the same input structures.

Consider the industry making steel tubes of n varieties (t_1, t_2, ..., t_n). Suppose the planners plan an increase in the output of steel tubes, the increase in the

5. Ibid., p.99.

total output to be accounted by only one particular type of tube (say t_1). Now if the planners calculate the new input requirements on the basis of an input norm which is a weighted average of the input norms of all the n types of tubes (weights can be the current relative output of the n types of tubes) then the new calculations will lead to inconsistent plans : The enterprises producing the types t_1 will have a shortage of some inputs and surplus of some others.

With every new iteration sought to close the material balances, the errors caused by aggregation might get magnified : each iteration might alter the planned output of an industry, and every new output may imply new relative outputs of the component commodities. Thus every time the degree of correspondence between the aggregate output and the input coeffcients used may decline and lead to wider and wider gaps between the plans compiled and a consistent one. Aggregation of commodities inevitably implies aggregation of input coefficients, which give rise to various inconsistencies. More will be said on this later.

Preparation of selective balances and aggregation, though it reduces the size of the problem from millions of equations to thousands of equations, leaves many products beyond the purview of the plan, thus giving rise to the possibility of shortage of or the waste of an unplanned commodity, and hidden shortages. When the balances are closed, there may be hidden shortage or surplus of unplanned commodities which are to be used as inputs in the production of the centrally planned products, depending on whether the output of the former falls short of or exceeds the requirements of their consumers. To quote the deputy head of one of the departments of Gosplan USSR : "one of the reasons for inconsistencies is that materials which are necessary for the production of centrally planned products are themselves not completely included in the list of centrally planned products, and therefore the balancing of production and requirements in the planning organs is not completed."[6]

Universality is further lost, when all the sources and uses of the product are not accounted for. Here, calculations are simplified in two ways : First, the enterprises using a particular product (which itself may be aggregated) are aggregated together under appropriate headings by industry, ministry etc.

This can lead to sources of error analogous to those in aggregating commodities. (i) The aggregation of requirements for commodities at particular places into requirements for commodities, and the subsequent disaggregation of the plan for commodities into supply plans of commodities to particular places, may result in loss of information as to where the commodities are needed.[7] (ii) the enterprises

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6. Quoted *Ibid.*, p.68

7. As the number of enterprises grows, problem gets increasingly difficult. It is to deal with this problem that small enterprises are discouraged in the USSR and production is concentrated in large-scale enterprises.

authorized to produce commodities being unaware of the particular enterprises to which the commodities will be delivered, may ignore the needs of the consumers.

(iii) Inconsistent plans may be compiled because the methods of aggregating enterprises may be inconsistent. An assumption inherently implicit in such aggregation is that input structures of the enterprises are the same and that their relative outputs will remain unchanged.[8]

Second, the concretely planned items are listed only according to the requirements of the main consumers. The consumption of small items is not planned concretely in the balance, is expressed only globally in an aggregate form in a residual column : 'other uses'.[9] Such undefined, unplanned residuals can be quite large and thus introduce inconsistencies into the system.

All the factors discussed above, combined together make a material balance system very restricted in scope, and lead to a significant loss of universality in the system. Our consistency condition number one is clearly violated.

The balance system does not satisfy the second condition as the balances are not complete. "For many kinds of products material balances embrace little more than 60 per cent of the production. When commodity A is produced as a

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8. Ellman, n.4, pp.99-100.

9. See Kornai, n.1, pp.7-9.

subsidiary product of enterprise X belonging to industry B, then X's output of A may not be known to the central planners nor to the sectoral planners responsible for the A industry."[10]

Even after all the reductions made in the number of equations and the variables therein, the amount of computational work to be done is immense. It is impossible for a single centre as Gosplan to prepare all the equations, whose number is still formidable. To simplify matters the preparation of the balances of products is split up among various organisations. More than 20,000 material balances are prepared in a complex multilayer system. Information is incomplete, but the overall picture appears to be as following : Gosplan prepares 1,200 or more material balances for key products; in the process of preparation of these balances, input requirements of tens of thousands of products are considered. An additional 18,000-20,000 material balances are prepared by the council of the National Economy of the USSR, the main administrations of inter-republic deliveries and republic administrations attached to the Gosnab.[11]

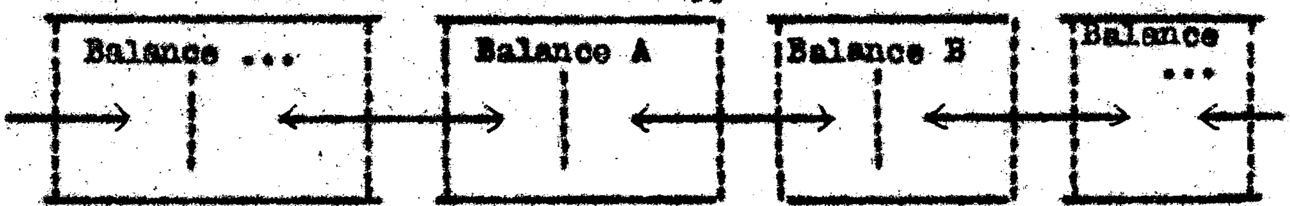
Mxk With different organisations balancing different commodities each material balance is primarily concerned with balancing the output and requirements for a single commodity. The balances at different levels are not

10. <u>Ibid.</u>, pp.72-73.

11. Figures from V.G. Treml, "Input-Output Analysis and Soviet Planning" in J.P. Hardt (et al) (ed), <u>Mathematics and Computers in Soviet Planning</u>, (Yale, 1967),pp.78-79.

completely collated, and together they do not form an integrated system. In other words balances are not compiled as an interlocking set. As Ellman has illustrated diagrammatically the compilers of material balances are doing calculations of the type[12] :

rather than calculations of the type



The Structure of interdependence in an advanced Soviet type economy is such that no single balance equation can be adjusted without having repercussions on a whole series of other balance equations, as output of one balance equation enters as an input in another equation, whose output in turn again enters some other equation etc. etc. Consider a commodity A in the production of which commodities a_1, a_2 .... xx a_n are being used as inputs, directly or indirectly. Then a change in output of commodity A will entail a change in outputs of all the commodities ($a_1, a_2 \ldots a_n$). If during the process of balance calculations output of A is altered then consistency requires that suitable

12. Ellman, n.4, p.73.

adjustments be made in balance equations of commodities ($a_1 \ldots a_n$) and in turn in all equations affected by changes in outputs of $a_1, a_2 \ldots a_n$.

The calculation of these changes is a task demanding immense labor and the planners time table allows a recalculation only of the so-called 'first order' and possibly at most 'second order linkages' or effects of an initial change, but no more than this. In other words whereas consistency requires the evaluation of the convergent series :

$$X = (I + A + A^2 + A^3 \ldots + A^n) Y$$

where X = gross output vector

I = Identity matrix

A = Matrix of direct input coefficients

Y = final demand vector

it often happens that X is approximated by considering the first two terms only.[13]

This inevitably leads to an inconsistent plan. The degree of inconsistency, however, will depend on the ratio of direct inputs to full inputs and the number of iterations required for consistency. On the basis of the 1959 input-output table for the USSR in value terms, TsSU has calculated that the ratio between direct and full inputs usually ranges between 1 and 2, but that much larger values ranging upto

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13. <u>Ibid.</u>, p.73.

54.7 occurred quite frequently. Levine has estimated that number of iterations required for the estimated value of X to attain the true value of X range between 6 and 13.[14]

As against this two Soviet economists using Soviet data have shown that in many cases two rounds of iteration were enough to bring direct input coefficients quite close to full input coefficients.[15] Similarly Montias has shown that in case of an existence of capacity bottlenecks the number of iteration can be reduced. If the outputs in the excess capacity sectors are adapted to the potentials of the bottleneck sectors, the planners can arrive at a consistent plan without matrix inversion.[16]

Dobb[17] has argued that the number of iterations required for consistency can be reduced if the coefficient matrix can be arranged in a quasi-triangular form. This implies an absence of complicated feed-back relationships or what is called 'circular relations'. A significant result which emerged from the 1959 input-output table for the Soviet Union was that a comparatively small group of productive links have decisive importance in the system of

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14. See Ibid., p.74. (also see L.Ya Berri(ed), Planning a Socialist Economy, Vol.1, (Moscow, 1977), p.169.
15. See Ibid., p.74.
16. J.M. Montias, "On the consistency and efficiency of central plans", Review of Economic Studies, Oct. 1962.
17. Dobb, n.2, p.359.

inter-branch links. Of the 4000 inter-industry linkages exhibited in the table, about 500 only accounted for more than 95 per cent of all material expenditures.[18]

All these arguments notwithstanding, the fact remains that when plan-targets are adjusted upwards, there is no guarantee that available supplies of essential inputs on which the achievement of the targets depends, will always be adjusted, or can in the circumstances be adjusted to match. In the ultimate analysis the calculated inter-relationships on which the final set of plan-targets is based can be no more than an approximation. This approximation in terms of consistency need not lead to large deviations at the global level, but at the level of particular enterprises, and in the case of particular products, they could be considerable — large enough on occasions to be the cause of dislocation and serious bottlenecks. The major source of the problem, as pointed out earlier lies in the division of responsibilities ~~away~~ among various centres. Thus every organisation or person, Gosplan downwards, which takes part in the preparation of the balances is directly responsible for certain specified variables and certain specified balance equations. Each of them bargains about his own figures, and does so in such a way as to secure the balance of his own equation. "Nobody, not one participant of the

18. *Ibid.*, p.359.

plan coordination can survey the whole plan equation system. Not even those who occupy peak positions in planning can survey the whole equation system; even they deal only with certain variables and certain equations. Usually with the variables and certain equations which they consider the most important."[19]

In the absence of a system of interlocking balances (violation of condition number 3) a simultaneous closing down of all the balances can be compared to an attempt to solve a simultaneous equation system of gigantic proportions with the method of 'trial and error', a method of reconciliation by gradual approximation. In Kornai's words : "When the plan coordination begins, in fact one cannot know for certainty if there is a solution to this gigantic system or not; whether it has a single solution or several; and of course it is not proved whether this process of reconciliation converges toward some solution," and further "a certain heirarchy among the plan equations has developed. A certain unpronounced, undeclared but tacitly still recognized priority order has developed among the practical planners : in what inter connections an absolute equilibrium must be reached and in what sectors a potential disequilibrium can be at least tacitly tolerated; what plan figures must be planned with great precision and in which cases a higher degree of inaccuracy can be admitted."[20]

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19. Kornai, n.1, pp.18-19.
20. *Ibid.*, p.19.

The method of material balances assumes that the process of production can be represented by a matrix of fixed coefficients (the norms a_{ij}'s). Technical norms, in general, are unrealistic to start with, since they usually assume a quality of material inputs and conditions of repair and maintenance of equipment which are not normally met in practice. 'The output mix of an industry is frequently so complex that materials needs can only be gauged in proportion to the gross value of output of the industry or of a group of products rather than for each of the products separately.'[21] This in turn leads to our familiar problem of aggregating the norms — which in practice is extremely difficult, as even at the level of an enterprise different plants or shops may have different norms. For instance, there are as many norms of coal utilization as there are furnaces and boilers in a plant. The magnitude of inaccuracies, consequently, produced when aggregation is done at the level of an industry can be quite substantial, and their overall effect for a whole system of balances will be even greater. The norms used in calculations are generally averages weighted in favour of the more efficient producers. As a result, for efficient producers the norms may be too soft and provide no incentive to efficiency and conversely, for inefficient producers they may be impossible.

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21. J.M. Montias, 'Planning with Material Balances in Soviet type Economics', in A. Nove & D.M. Nuti (ed) <u>Socialist Economics</u>, (Penguin 1972).

A major problem with norms arises in keeping them abreast with rapid technical changes. Even if technical change is absent, input norms have to be updated with changes in output patterns. In a rapidly changing advanced socialist economy like Soviet Union's, changes in product mix are significant enough to render norms obsolete very fast. Errors caused by inconsistent aggregation will be larger, the faster the changes in product-mix in the absence of updating of the norms as the latter changes.

The assumption of fixed norms is a very strong one as it 'rules out substitutiability, non-proportional inputs, learning by doing and non-constant returns to scale',[22] and none of these obtain, in general, in the process of production. Consequently, material balance calculations cannot be expected to yield consistent results.

IV

Input-Output and Consistency

IV.1 As already mentioned in the introduction, the idea of an input-output balance was explicit in the 1923-24 Balance-Sheet of the economy prepared by TsSU. With Barengol'ts pioneering work on technical coefficients, the background had been prepared for Leontief. Leontief's contribution was threefold[23] ;

(1) He was the first to combine the two tables, one showing the balance of production and the other

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22. Ellman, n.4, p.74.

23. Nemchinov, in Alec Nove (ed) The Use of Mathematics in Economics, (London, 1964), p.12.

showing how the social product and national income was distributed.

(2) He increased the number of branches in the social economy, shown in the 'chess board' table of 'objects of labour'.

(3) He gave a mathematical interpretation of the balance sheet by constructing equations relating input and output, as Walras and Dimitriev had done earlier.

The table so developed by Leontief was divided into four parts with the focus on the top left part showing a chess board type arrangement of inter-industry transactions.

Actual studies of input-output techniques in the USSR began in the mid 1950's. In 1959 the government gave official instructions to TsSU and Gosplan to compile input-output tables. Since then, an impressive amount of work has been done in the USSR on the compilation of input-output tables. TsSU has compiled ex-post, accounting flow input-output tables for the USSR in value, physical and labor terms for 1959, 1966 and 1972. A capital-stock matrix for 1966 was also compiled. Planning input-output tables in value terms for 1962, 1970 and 1975 have been compiled by the Gsopaln's Research institute. Work on a planning table for 1980 is on. Research organisations have compiled a large number of regional input-output tables, a field in which the Central Economic-Mathematical Institute (TsEMI) has been active.

The Soviets now regard the input-output table as a main tool of solving the consistency problem, or in their terminology - achieving the balance of the national economy.

They see it as "the most methodologically advanced and experimentally tested model used in the practical work of making planning calculations."[24]

Soviet planners have repeatedly stressed in the past that input-output methods are not to replace the traditional balance method, but to be gradually introduced into the planning system. In 1962 Eidel'man wrote : "It would be wrong to think that the interbranch balance could fully take the place of the balance methods applied today in Soviet statistics and planning for the study and planning of interrelationships and resources."[25] In a paper written as late as 1978 Yefimov has once again stressed that "the interbranch balance does not replace the traditional balance calculation methods, but develops them, linking together general, macroeconomic indicators with more detailed production ones, particularly with the volume of production by individual industries."[26]

The expost interbranch balances prepared by the Soviets can be described as traditional Leontief type- Static, open input output tables. A difference between the Soviet tables and their Western counterparts lies in the

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24. Berri, n.14, pp.153.

25. M. Eidel'man, "The inter-branch balance of the National economy", Problems of Economics, August 1962, Vol.V, No.4, p.4.

26. A. Yefimov, "Interbranch balance and national economic proportions", in Economic Growth and resources Problems of the Contemporary World series, No.52 (Progress), p.22.

classification of services. Applying the Marxist definition of national income, all services (with the exception of freight, transportation, communications serving production, and various trade and distribution activities) are shown under final demand. A minor difference obtains in the numbering of the four quadrants of the table. Soviets have reversed the numbering of the first and second quadrants as applied in the western tables — thus final demand is quadrant II.

In terms of their economic content, each of the four quadrants of the export table in value terms characterise 'individual aspects of the reproduction process.'[27] The first quadrant reflects the production relations among branches. The data of this quadrant are the basis for calculating coefficients of direct and total expenditures. In Marxian terminology, quadrant I reflects the process of the simple reproduction of the means of production i.e. it shows what part of the social product is used to make up for the means of production consumed in the process of production.

Quadrant II shows the utilisation of final demand for non-productive consumption, accumulation and exports. Consumption is divided into personal and social. Accumulation is shown in two colums (a) the increase in fixed

27. Eidel'man, "The New Export Interbranch balance of Production and distribution of output in National Economy of the USSR", Problems of Economics, May 1973.

productive and non-productive capital and (b) the increase in circulating capital, stocks and reserves. Quadrant II depicts 'expanded reproduction' and the process of non-productive consumption.

Quadrant III shows the composition of the national income in value terms. The breakdown of net output for each sector is shown in terms of wages, profits etc. There is provision for amortisation of fixed production assets. Quadrant IV presents certain elements of redistribution of the national income : wages of people working in the non-productive branches, incomes of non-productive enterprises and organisations, etc.

The first expost table was prepared by TsSU for 1959. The table in value terms covered 83 sectors of 'material production'. A similar input-output table for the same year was compiled in physical terms covering 157 products.

The table lends itself to traditional Leontief-type mathematical treatment :

It is assumed that coefficients of production are fixed. Thus $x_{ij} = a_{ij} X_j$

where x_{ij} = sale of sector i to sector j.

X_j = Output of sector j.

a_{ij} = Sale of sector i per unit output of sector j.

For every sector i, it can be written in a linear form :

$$X_i = \sum_{j=1}^{n} a_{ij} X_j + Y_i \quad (i, j = 1 \ldots\ldots n)$$

where X_i = Output of sector i

X_j = output of sector j

Y_i = final demand for sector i

a_{ij} = input coefficient.

In matrix terminology, the whole system of linear equations for the n sectors can be written as :

$X = AX + Y$ where X = vector of gross outputs

or $X - AX = Y$ A = matrix of coefficients of direct inputs

or $(I-A)X = Y$ Y = vector of final demand

or $X = (I-A)^{-1}Y$ I = identity matrix

Previously we had mentioned that consistency requires the evaluation of the convergent series :

$$X = (I + A + A^2 + A^3 \ldots + A^n)\,Y$$

The input-output satisfies this requirement as the inversion of the matrix $(I-A)$ gives us the value of the convergent series. Mathematically it can be shown that :

$$(I-A)^{-1} = (I + A + A^2 + A^3 \ldots + A^n)$$

In economic terms, the inversion of $(I-A)$ gives us the coefficients of <u>total</u> material inputs consumed in the process of production, the total of direct and indirect inputs. This means that the full effect of a change in output of one or more commodities can be worked out straight from $X = (I-A)^{-1}Y$. There is no need to go through the time consuming process of iteration.

Thus, mathematically speaking, an input-output table gives us a vector of gross outputs 'consistent' with a given vector of final demand or vice-versa. In other words, mathematically, the input-output offers a consistent solution. Unlike the system of material balances, the input-output forms an interlocking integrated system. The input-output satisfies another of our conditions (see section III of this chapter) for consistency. The input-output tables are complete, that is they do include all the outputs of particular industries. But the other two conditions regarding technological assumptions and universality are not met by the input-output technique and it fails to offer a solution to the consistency problem. Some of the major problems arising in the use of input-output tables in Soviet planning are discussed below.

IV.2

LIMITATIONS

Two sets of limitations can be identified in the usage of input-output as a tool of 'consistency' planning. The first kind of problems are inherent in the concept of input-output arising from the assumptions made in the analysis. These limitations are universal, in that they would apply to all situations where input-output is being applied. The second set of limitations are more specific and contextual and are related to the nature of the economy in which the technique is being used.

The first set of limitations are introduced by the basic assumption of the input-output method that technological relations in production can be represented by fixed coefficients. In this case the assumption is much more rigid than in the case of material balances, where there is scope for flexibility. The implications of this assumption have been well discussed in literature, and we need not go into them. We have already attempted a brief discussion on the subject in the section on material balances. All that need be said here is that fixed coefficients imply an absence of alternative techniques of production ruling out substitution of inputs, increasing or decreasing returns to scale and non-linear relations between outputs and inputs. None of these obtain in real economic life, and gross inconsistencies can result from these simplifications.

The second set of problems are in most instances uniquely Soviet, in that they are a product of the current institutional setting and the level of development of the Soviet economic system. The most difficult part of compiling an input-output table is the collection and processing of the requisite statistical data. Consistency, as defined before, requires that data should be collected from all the ~~the~~ production units and should report the economic activities of the enterprises accurately.

In this sphere, however, there is much to be desired and the "existing statistical accounting does not make it possible to collect all the information that is required for the construction of the export interbranch balance."[28] In 1959 and 1966 this shortcoming was sought to be overcome by obtaining data on expenditures on production in industry and construction from sample surveys. The 1972 table was an improvement on the 1959 table and was based on a wider coverage with 'an across-the-board survey of the greater part of all industrial enterprises and construction enterprises'.[29] Rest of the enterprises were covered by a sample survey. However, the data is still subject to a lot of discrepancies and inaccuracies. Moreover, the existing data on production and consumption of agricultural products produced on their private plots by collective farmers and others are not very reliable.

The technological assumptions embodied in input-output analysis require classification of economic activity according to 'pure sectors' i.e. sectors producing homogeneous products. Such a classification leads to three kinds of problems.

First, problems of inaccuracies and unreliability arise as the classification requires a lot of data reporting

28. Eidel'man, "The new export Interbranch balance ... in the national economy of the USSR", Problems of Economics, (May 1973), p.22.

29. Ibid., p.7.

and processing. The enterprises covered by a sample survey, are asked to give data regarding structure of outlays for producing goods typical of the sector and for subsidiary products. On the basis of the survey reports subsidiary production is deducted from the output of each sector and added to the production of the corresponding sectors. Such subsidiary production in the Soviet Union is quite substantial in many cases, (See Table I), as the Soviet enterprises are not so specialised and have a lot of intra-enterprise dependence. The vast mass of calculations and the flow and counter-flow of data may lead to inconsistencies in the final version of the plan.

Second, since computational problems do not permit a separate branch for each product, a 'pure branch' is in fact an aggregate of a type of output. This necessarily entails aggregation errors analogous to those pointed out in the discussion on material balances. Apart from these, aggregation may result in an insufficient differentiation of the branches. For instance, in the 1959 balances, production of all types of building materials was classified under one head, while a great number of different type branches were collected in a group entitled "other branches of food industry".[30] The problem has not been solved, as yet. The 1972 table suffers from similar defects and the

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30. L. Berri, F. Klotsvog, S. Shatalin, "The Inter-branch Balance and Its use in Planning", Problems of Economics, August 1972, p.21.

TABLE I

RELATIONSHIP BETWEEN MAIN AND SUBSIDIARY PRODUCTION IN SOVIET INDUSTRY

(1) Industry	(2) Volume of production of the industry's product produced in enterprises belonging to the industry itself	(3) Volume of production of 'foreign' products produced by enterprises belonging to the industry as % of the Column (2)	Volume of production of the given industry produced by enterprises belonging to other industries as % of Column(2)
Wine-making	100	0.5	139.9
Medical instruments and equipments	100	331.2	90.4
Concentrated feeds	100	—	87.0
Equipment for the building materials trade	100	202.3	81.0
Electricity and thermal power generations	100	1.5	66.7
Tractors and Agricultural Machinery	100	40.6	64.0
Constructional Engineering	100	72.8	48.2

Sources : Ellman, n.4, p.77.

sectoral differentiation in it is only slightly more advanced than it was in the 1959 table. The number of sectors in 1972 has been increased to 116 as against 83 in 1959. Indeed the problem will exist so long as an input-output table is not universal i.e. covers all the products.[31]

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31. The process of aggregation will yield satisfactory results only when a change in the production pattern within the consolidated group of sectors does not influence the aggregated coefficients. In practice there can only be an approximative solution to the aggregatan problem. An optimal solution is that which minimizes these errors. Kossov suggests a method of optimal aggregation. i sectors XXXX(i=1... ...n) can be aggregated if there exists significant correlation between them, reflected in correlation coefficients relating all the i sectors to one another. The condition to be satisfied using correlation coefficients can be worked out mathematically. Within the bounds of this condition, that scheme of aggregating industries which resultsin a minimal increase in the determinant of the matrix of correlation coefficients of the sectors concerned, may be called optimal. See V. Kossov, "The theory of aggregation in input-output models", in Carter and Brody (ed.), Contributions to input-output analysis (Amsterdam 1970).

According to Nemchinov, 'the following two principles of aggregation should be adhered to simultaneously (a) classification rather than combination should be used (b) the main decisive mass of output, embraching 75 or 80% of the total production of the given type should be singled out, the remainder being aggrogated in a less homogeneous unit. For example, open pit and mined deposits may be designated for power producing coal, while this designation is not expedient for coking coal inasmuch as open pit excavation of coking coal is not widespread to any important extent. Wheat and rye should be included entirely in the production of food cereals, although in the columns of the balance table a part of this grain will be shown as used for seed and feed. See Nemchinov, "Some Theoretical Questions of Interbranch and Interregional Balances of Production and Distribution of output", Problems of Economics, Dec. 1960, p.14.

Thirdly, the indices of an input-output table which refer to the outputs of 'pure' sectors violate the important plan principle of adresnost; which means that there should be no plan targets which are responsibility of no-one in particular. To each plan target there should correspond an organisation (address) responsible for implementing it. Consequently, the indices 'have to be recalculated to fit the plan industries which is not difficult but which does not enhance the reliability of the results'.[32] Inconsistencies can be expected on all the three counts.

A related problem is whether intra-plant turnover should be included or excluded from the production outlays for enterprises. The former is known as the gross turnover method, and the latter as gross output method. The practice of accounting and planning requires that input-output tables be prepared in gross output indices i.e. they should reflect only the commodity relationships between enterprises. However, from the planning point of view, both commodity and technological relationships need to be shown. For a complete view of the latter, all the enterprises should report their subsidiary activities precisely, and a gross turnover method should be used, especially in the case of the Soviet Union as the Soviet enterprises are less specialised. Both the methods have been used in the Soviet Union. TsSU

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32. Ellman, n.4, pp.87-88.

favours the use of the gross output method and TSEMI the use of the gross turnover method. In the Soviet case, use of the gross output method implies loss of knowledge of a substantial portion of production and technological relationships. The use of the gross turnover method, on the other hand, will make the balance table non-comparable with the existing accounting and planning data. Hence both the methods will lead to inconsistencies, which, however, will be less pronounced in the case of the gross turnover method.

One of the most complex methodological problem associated with the use of input-output in planning stems from the hybrid variety of the Soviet price mechanism. This has been an area of intense controversy. Many Soviet economists consider the choice of consumer over producer prices as irrational. The use of consumer prices leads to double counting of trade and transportation costs and this exaggerates the volume of production in some branches and the aggregate social product. "This in turn leads to some distortion of the branch structure of the aggregate social product, utilized national income, the replacement, accumulation and consumption funds and also the structure of expenditure for output by the principal elements and makes it impossible to compare these indices with planning and final statement figures".[33]

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33. Berri, Klotsvog, Shatalin, n.28, pp.22.

According to Eidel'man current prices donot reflect the 'socially necessary expenditure of labour' and deviate from the latter in one or the ether direction and accordingly inflate or deflate the relative share of a branch in proportion to the gap between current prices and socially necessary labour expenditure.[34] These deviations are partly the result of the turnover tax which is highly differentiated for different groups of consumers in the USSR. An idea can be had from the following example : Soviet agriculture employes around 40% of the labor force, but its share in the gross output is only 16-17%, and its net output only 20-22% of the country's national income, when current prices are used for evaluation. About three fourths of the turnover tax is from products produced from agriculcutral raw materials and one-fourth from products, using industrial raw materials. If the turnover tax on industrial output is distributed in preportion to labour outlays among all the branches participating in production and distribution of these products (agriculture, light and foodstuffs industries, transport, trade) this along will increase the share of agriculture in national income by 8%.[35]

The proponents of the use of consumer prices retort by pointing out the almost insurmountable difficulties of obtaining the flow data in producer's prices. TsSU prefers

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34. Eidel'man, "Methodological problems in the Analysis of the Balance of National Economy", Problems of Economics, March 1966.

35. [illegible], Ibid.

consumer prices, while TSEMI argues for producer prices.[36] Unless the pricing debate is conclusively resolved in the USSR, inconsistencies in planning are to be expected on this count.

Another source of difficulty lies in the non-correspondence and definitional discrepancies between input-output tables in value terms and those in physical units. The two types of tables differ in their definitions of intrasectoral turnover and in their categories of final demand. The commodity coverage and classification is different in the two tables. The use of consumer prices in value tables adds to the non-comparability.

Models in physical units suffer from various defects. They do not show value-added elements and the generation and redistribution of national income, and cannot be used for overall balancing of flows. The major problems, however, lies in the units to be used in the physical input-output tables. The input-output model assumes that each industry produces a single, uniform product, whereas each industry produces a heterogeneous collection of goods. To solve this problem the Soviets measure output not only in natural physical units but also in conventional physical units and money.

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36. In the 2 volumes on socialist planning (ed) Berri, n.14, it is argued that producer prices be used. If these volumes can be taken as reflecting the recent trends in official thinking, then it can be suggested that in future producer prices would be preferred to the current usage of consumer prices.

'Conventional physical units (e.g. the measurement of various fuels in tons of coal equivalent) are used where it is clear that natural physical units do not reflect consumer's valuations.'[37] In case of industries producing very heterogenous outputs (for ex. engineering or furniture industry), money units in constant prices are used to measure output. The construction of a physical input-output table, using either conventional units or money, ineivitably aggregates commodities and introduces aggregation errors. Thus, while on the one hand, the physical tables in themselves are incapable of leading to consistent plans, the less of correspondence and comparability between the physical and value tables, on the other, excludes the possibility of rectifying the sources of error introduced by one, by comparing it with the other.

The Soviet planners have not been able to overcome the problem of showing depreciation of capital equipment in the input-output table. Every enterprise makes deductions according to definite norms, and these deductions are included in production costs. 'As an element of material production expenditures, depreciation must be reflected in quadrant I of the intersectoral balance as compensation for the wear and tear of every type of equipment, spare parts, structures and buildings.'[38] However, the

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37. Ellman, n.4, pp.77-78.
38. Eidel'man, n.25, p.7.

Soviet accounting records do not permit the calculation of such figures, and depreciation is shown in a row justn after the column totals of quadrant I. A perusal of the 1959 and 1972 tables shows that the problem stays unresolved. Again, inconsistencies can be expected on this score.

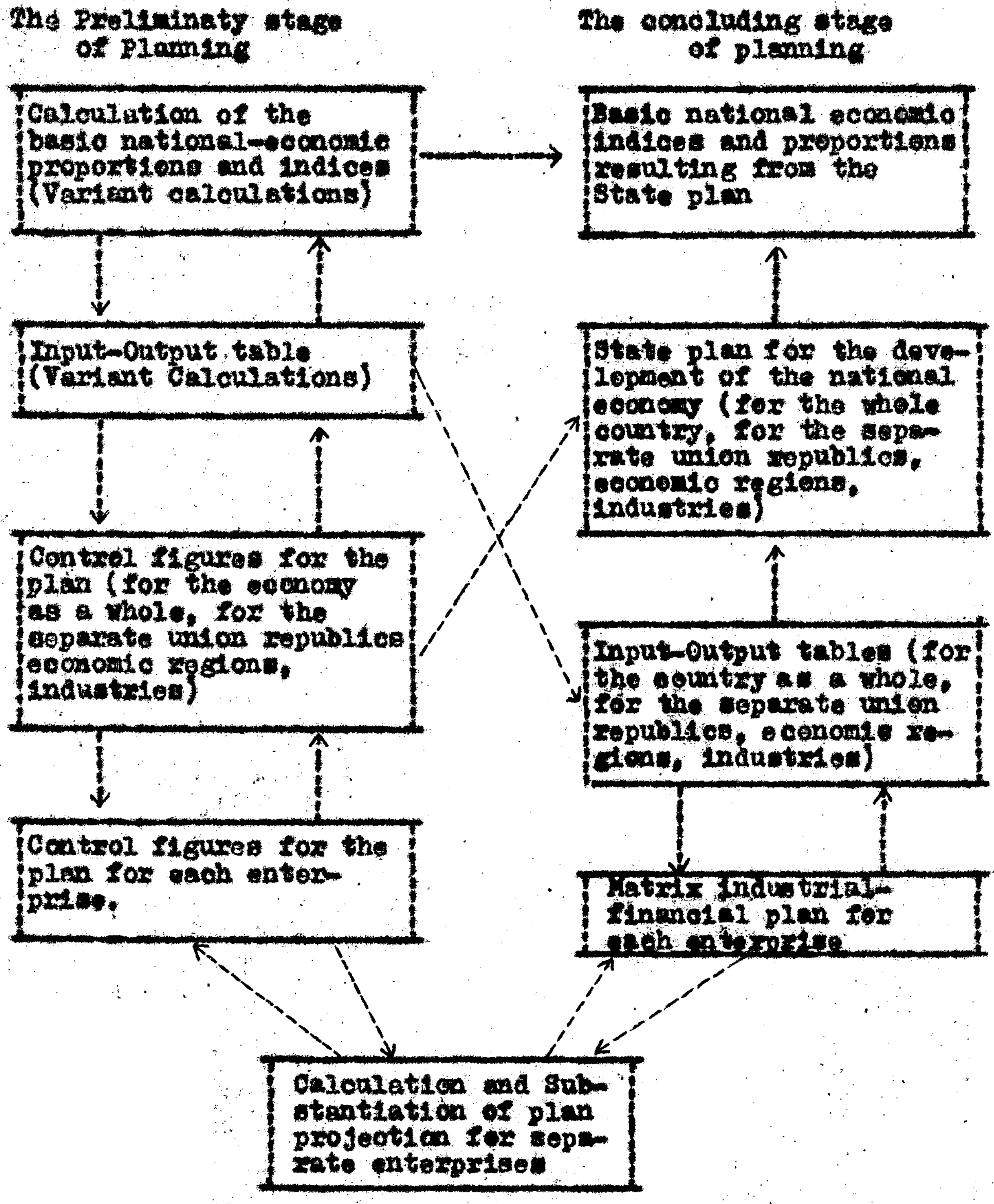
The problems discussed so far obtain in the compilation of all static input-output tables, expost or exante. The usage of extante or planning input-output tables, however, raises further problems, which are in a sense specific to planning input-output tables. The place of input-output tables in the overall planning process is as follows :

The broad indices of the plan in Soviet Union are provided by the macroeconomic balance for the national economy. Within the framework provided by the above balanse, input-output is used as a planning technique at lower levels of the planning hierarchy to plan the relationships between the various industries. It forms a link between the basic national economic indices and the plans for separate industries and regions. The suggested use of input-output can be illustrated as in figure II.[39]

The integration of input-output into the planning process has proceeded quite slowly in the Soviet Union. There are many problems. A major hindrance is posed by the non-comparability between the indices of the plan derived from

39. From Ellman, n.4, p.82.

Figure II


The Preliminaty stage of Planning
The concluding stage of planning
Calculation of the basic national-economic proportions and indices (Variant calculations)
Basic national economic indices and proportions resulting from the State plan
Input-Output table (Variant Calculations)
State plan for the development of the national economy (for the whole country, for the separate union republics, economic regions, industries)
Control figures for the plan (for the economy as a whole, for the separate union republics economic regions, industries)
Input-Output tables (for the country as a whole, for the separate union republics, economic regions, industries)
Control figures for the plan for each enterprise.
Matrix industrial-financial plan for each enterprise
Calculation and Substantiation of plan projection for separate enterprises

the macro-economic balance and those of the input-output table. The input-output tables are complete i.e. include all the output of particular products, whereas the plan calculations take into account output only from the major sources, ignoring the small industrial enterprises run by various state and collective farms, consumer cooperatives etc. Then the plan and the input-output tables differ in their product classification. While comparing the 1959 physical input-output table with the plan indices, only 77 products were found comparable, 80 products in the input-output table were not in the plan nomenclature and 33 products in the plan nomenclature were not in the input-output nomenclature.[40]

The inconsistencies between the national plan and the input-output tables will remain as long as there are shortcomings in the system of accounting and planning information. The problem can be solved only by an overhauling of the present procedures and with the framing of a uniform statistical and accounting system, whereby all the economic and planning units resort to the usage of a uniform set of concepts and measurement techniques.

The main problems in preparing planning input-output models, however, arise in the estimation of future technology, future consumption, future exports and imports and future

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40. Ellman, n.4, p.83.

capital investment.

The assumption on which the input output equation systems are built —— material consumption in every product group is directly proportional to production —— cannot be maintained in planning for future periods. "Scientific technical progress, increase in labor productivity and price reductions, savings in materials, use of substitute products, changes in assortments and quality of production - these change the "linear functions" into really quite indeterminate functions.[41] The consumption of materials changes with changes in production. In USSR, a comparison of coefficients based on 1966 and 1959 tables reveals interesting results. During the seven-year period, for all machine-building, on the average, the expenditure of ferrous metals per 1,000 roubles of output declined by 25%; the decline for the individual branches in the industry was still greater : by 33% for hoist-transport equipment, by 26% for forging and pressing equipment, and by 50% approximately for machine tools. In the same industry there was an increase in the expenditure of plastics, electric power, gas and other most effective types of supplies and fuel.[42]

Nevertheless, the fact that input coefficients continuously change as a result of technical progress should not

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42. L. Volodarskii and M. Eidel'man, "Basic results of elaboration of the interbranch balance ... for 1966", Problems of Economics, Sept. 1969, p.44.

41. Martin, Karbstein and Rudich, [redacted], "Some findings based on the input-output table of aggregate production of the GDR." Eastern European Economics Vol. III. No. 2. Winter 1964-65 p. 45.

be used as an argument against employing the input-output table in both short-term and long-term planning and the calculation of alternatives. It has been estimated that : 1) the input coefficients, when compared year to year remain relatively constant, and 2) the input coefficients rise or decline at a constant rate over a period of several years; that is, there exists a specific, statistically quantifiable relation between the development of production and changes in the cost coefficients.[43] Consequently the data of an expost input-output table can be employed for short-term planning tasks and merely require minor adjustments. For long-term planning purposes coefficients can be projected for future years. The task of projection is made much easier by the fact that the vast majority of the coefficients are either zero or of negligible importance. Thus, only 11% of the combined number of all coefficients of direct expenditures calculated in RSFSR input-output table for 1966 accounted for 87.1% of all input expenditure.[44] Moreover, when changes greater than 100% were made in the 86.3% of the non-zero coefficients used in the 1959 input-output table, the volume of gross output in a sector, given final sectoral output changed less than 1%.[45]

In the planning input-output table for 1970 as part of the work on the 1966-70 five year plan, worked out by the

43. Martin, Karbstein and Rudich, n.41, p.46.

44. N. Guzenko, "Coefficients of direct and full expenditures", Problems of Economics, April 1972, p.38.

45. Berri, n.14, p.166.

Gosplan's research institute the less important coefficients were largely taken from the 1959 accounting table or extrapolated from it. The more important coefficients were projected by the 'method of technical-economic forecasting'.[46] 'Experience has shown that the big problem in projecting the technical coefficients is not in estimating technical progress in the production of goods already in production, but in estimating changes in the structure of production i.e. the 'birth' of new products and the death of old ones'.[47] This problem is acquiring significant proportions in the Soviet economy. For instance, from 1966 to 1975 41,300 new types of machines, equipment, apparatus and instruments were developed in the USSR and 9,900 were dropped. The rate of renewal is increasing - between 1971-75 for every 100 newly developed products, 37 were withdrawn. 'The problem of measuring the speed of structural changes has still to be solved'.[48] Unless the method of projecting coefficients

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46. Ellman, n.4, p.79, describes the method of 'technical economic forecasting.
Two basic methods of determining the planning coefficients of direct inputs are given in Berri, see p.165. Also "a key principle in organising planning on determining coefficients of direct material input for the planned period is that only those major coefficients playing a decisive role in the planning calculations of sectoral structure of social production using an inter sectoral- input-output table (several hundred coefficients) need be validated in detail technically and economically. The remaining ones can be drawn from the accounting inter-sectoral input-output tables compiled by the statistical boards or corrected on the basis of expert appraisals". Berri (ed), n.14, p.166.

47. Ellman, n.4, p.79.

48. Alexander Anchishkin, "Extended reproduction under developed Socialism", in Economic Growth and Resources Problems of Contemporary World Series, No.52, (Progress : Moscow 1978), pp.83-86.

accurately reflects all the structural and technological changes, inconsistencies in plan formulated on thesbasis will inevitably result, and their magnitude will be greater, the fu#ther away the target year from the base year.

Inconsistencies can also result from an inaccurate estimation of future capital investment. This aspect is particularly important for the Soviet Union, where gross capital formation amounts to 35% of the national income. When ~~Xxx~~ the planning input-output tables were prepared for the 1966-70 plan, the volume of investment required to support various alternative growth paths was in general calculated according to a mathematical formula. The industrial ~~xx~~ scientific research and design institutes worked out the norms used in determining the requirements of each industry in conformity with an overa ll methodology worked out by Gosplan research institute.[49] In this context, it is to be kept in mind that an adequate treatment of capital-investment is strictly speaking not possible within the static input-output framework. We have to examine the dynamic input-output for this purpose.

The traditional Soviet method of planning started with the ~~xxx~~ extrapolation of growth rates of gross output levels in key industries and sectors and most of the elements of the net product were determined as a residual after all the inter-industry requirements had been met. The input-output

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49. Ellman, n.4, pp.79-81.

method has served as a point of departure in drawing up the plan.[50] Trend is now towards beginning with a final demand vector and determining the gross output vector from $X = (I-A)^{-1} Y$. This approach has been criticized by the traditional planners as being a victim of consumptionism. However, the debate seems to have concluded in favour of the new approach. In the current stage of development of the Soviet economy it is appropriate to take final demand vector as the starting point. This is because the consumption fund, the proportion of which in the USSR's national income has been more than 70 per cent of national income over the last decade, to a large extent determines the branch structure of the economy as a whole.[51]

This leads to the problem of estimating the structure of personal consumption. Western economists have criticized the Soviet economists on their failure to develop a consumers theory embodying concepts like utility and income elasticities of demand. To this, it has been rightly pointed out by the Soviet economists, that in the Soviet Union, general production possibilities rather than demand xxxxx determines the volume of sales. The structure of personal consumption was determined mainly by extrapolation, xxxx when working out the planning input-output tables for 1970.

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50. V.G. Treml, n.11.

51. See Berri, n.14, pp.160-63, and Yefimov, n.26, p.28.

'The forecasts for social consumption are usually based on plan norms, for example the number of hospital beds required per thousand inhabitants.'[52]

As a technique of planning, it is difficult to reconcile input-putput with the traditional system of balances, let alone superseding the latter by the former, for the simple reason that the latter are prepared for more products than the former. To replace material balances, which are prepared for more than 1200 key products and overall for more than 20,000 products, would require matrix inversion of the degree, impossible with the current level of computer technology.

IV.3 Input-Output Vs. Material Balances : Variant Calculations

In the case of material balances it was argued that they are unable to compile consistent plans because they do not form an integrated system, are not complete, nor universal, nor does technology correspond to the strong assumptions implicit in the use of material balances.

Unlike material balances, as we have already pointed out the input-output does form an integrated system and the input output tables are complete, accounting for all the outputs of particular commodities. On the other hand, however, the technological assumptions of input-output are even more restrictive and rigid than those of material balances and

52. Ellman, n.4, p.79.

take the model further away into abstraction.

"Considered as a technique for drawing up consistent plan the most important defect of an input-output table is that it is not universal. The number of industries in the largest inputput-output table - 600 - is much smaller than the number of products for which material balances are regularly drawn up, and is so so small as to be scarcely relevant to the problem of drawing up consistent plans for 20,000,000 commodities".[53]

But all these shortcomings and the failure to solve the consistency problem, notwithstanding, the input-output table is a very useful addition to the techniques at the planner's disposal. It provides a revealing insight into structural make-up of the economy. Of particular importance is its ability to reflect both inter-industry and general economic proportions. It "enables us to determine such important indices as the relationship between departments I and II of social production, the organic composition of capital, (C/V), the rate of surplus product (m/v) and some very important national economic indices".[54] Thus it can reveal problems affecting particular branches of production, can provide data for the analysis of efficiency of production, price formation etc. 'At the same time, the inter-branch balance is more than just an economic table : it is an economico-mathematical model of the national economy."[55]

53. *Ibid.*, p.88.

54. Nemchinov, n.31, p.15.

55. Yefimov, n.26, pp.24-25.

and given the assumption of constant coefficients 'may be used as a basis for solving a number of extreme problems and choosing the optimum variants of the balance.'[56]

Material balances do not permit variant calculations because of the tremendous labor-intensity involved in the task. Variant calculations are of great use in perspective planning as they enable experimentation with various alternative growth paths and selection of the best.

The Soviets made the first major use of variant calculations in connection with the compilation of the 1966-70 five year plan. Gosplan's research institute examined the impact on the rate of growth of national income and consumption of the various feasible shares of capital accumulation in the national income for 1966-70. Variant calculations led to the conclusion that increases in the share of accumulation would lead to increases in the rate of growth of national income but that this would have very little effect on the rate of growth of consumption, as almost all the output increases would be in the form of producer goods. The results of the calculations are set out below :[57]

TABLE III : STRUCTURE OF THE NATIONAL CINCOME FOR 1970(IN %)

Components of the National Income	Variants				
	I	II	III	IV	V
Consumption	75.2	73.8	72.4	71.0	69.6
Accumulation	24.8	26.8	27.6	29.0	30.4
of which industrial fixed capital	9.0	10.5	12.0	13.5	15.0

57. Source : Ellman, n.4, pp.86-87.

TABLE IV : AVERAGE GROWTH RATES FOR 1966-70 (in %)

	Variants				
	I	II	III	IV	V
National Income	5.6	6.1	6.6	7.1	7.5
Consumption	6.7	6.8	6.9	7.0	7.0
Accumulation	2.5	4.1	5.7	7.25	8.7

The tables show that any sharp increase in the share of accumulation in the national income would lead to a corresponding sharp decrease in the share of consumption in the national income, and only a small increase in the rate of increase of consumption (within a five year plan period).

With the share of accumulation it was possible to work out the corresponding rates of growth of the capital goods sector and other industries :

TABLE V : OUTPUT OF STEEL ON VARIOUS ASSUMPTIONS

	Variants				
	I	II	III	IV	V
Production of Steel in 1970 (millions of tons)	109	115	121	128	136

TABLE VI : AVERAGE GROWTH RATES OF SELECTED INDUSTRIES 1966-70

	Variants				
	I	II	III	IV	V
Engineering and Metal Working	7.1	8.2	9.3	10.4	11.4
Light industry	6.5	6.6	6.8	7.0	7.2
Food	7.1	7.3	7.4	7.5	7.6

In the current phase of the Soviet economy, when the planners are changing their priorities from concentration on the capital goods sector in favour of a more balanced development of both consumer and the capital goods sector, the input-output technique has yielded an important result of great practical significance that an increase in the share of accumulation while speeding up the growth rate of the economy as a whole, does not provide for a marked increase in the growth rate of consumption. Undoubtedly, as a technique, the input-output can be of an immense use in economic policy formulation.

However, the input-output does not guarantee that the otpimum variant is present among the variants calculated. The great deal of painstaking labor involved in preparing a number of variants does not permit the calculation of the set of all the possible variants and then identifying the optimum one. For this "it is always necessary to rely on general methods of programming especially if it is a question of using modern mathematical and electronic computers."[58] This leads us to our next chapter.

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58. Nemchinov, n.31, p.15.

CHAPTER III

LINEAR PROGRAMMING AS A TOOL OF OPTIMAL PLANNING

LINEAR PROGRAMMING AS A TOOL OF OPTIMAL PLANNING

The traditional methods of calculation employed by Soviet planners were unable to explore the possibilities of optimising on the use of resources. Optimisation received scant attention in Soviet planning mainly due to the operation of the following two factors : Firstly, the Soviet strategy for growth, till the mid-50's, was designed to achieve a rapid expansion of a few priority sectors, and questions concerning efficiency were considered secondary. Second, even if the Soviets were to apply themselves to endeavour an efficient utilization of resources, the premature state of mathematical economics and cybernetics and yet underdeveloped state of computer technology would have offered little scope for the success of such attempts.

However, mid-50's onwards the question of optimisation acquired increasing relevance, as the above mentioned factors gradually disappeared from the stage. The credit goes to the mathematical economists who were able to focus attention on the need for a most efficient utilisation of the existing and planned resources, and the irrelevance and obsolescence of the traditional methods of calculation if the optimum in economic planning was desired. The need of the hour, decreed the cyberneticians, was to increasingly avail the services of mathematical methods in general and linear and non-linear programming in particular.

Linear programming was discovered in the late 1930's at the Leningrad University Institute of Mathematics and Mechanics as a technique for solving certain production problems arising in the construction of optimum plans for machine loads, the laying out of sheet materials and timber cutting, where targets involving a range of products had to be met. Public knowledge of this technique dates from the appearance of Professor L.V. Kantorovich's 'Mathematical Methods of organising and planning production'. Kantorovich called the technique 'the resolving multiplier method'.

Later, and almost independently of this work, a similar method began to be widely developed in the United States and Britain. Subsequently, the appellation 'linear programming' became attached to the technique in foreign literature.

Many problems can be solved in production planning by the use of linear programming. For instance, selection of the optimum version of the plan, the disposition of means of transport for the conveyance of various types of freight and passengers from particular starting points to particular destinations, the combined utilisation of valuable raw material components, the distribution of orders among factories and so forth.

Linear Programming can be applied to the solution of particular problems where the targets to be optimised are strictly defined, and the optimisation is constrained by the limitations of available resources (productive capacity, raw materials, available labour resources and so forth), which in turn are known in advance. The conditions of the problem usually include some system of interrelated factors, the availability of resources and a knowledge of the conditions limiting the way in which these can be used. The problem becomes capable of solution once definite valuations emerge both for the resources and for the expected results. A result obtained on the basis of programming has a relative character and is optimum only in terms of the constraints introduced. A standard linear programming, thus, has three aspects :

(a) A strict criterion of optimality.

(b) The presence of a system of interrelated factors.

(c) A precise formulation of the conditions limiting the use of available resources.[1]

Mathematically, a standard static model can be set out in the following manner. The task is to maximize or minimize the objective function :

$$\sum_{j=1}^{n} c_j x_j \longrightarrow \max.$$

subject to,

$$\sum_{j=1}^{n} a_{ij} x_j \leqslant b_i \qquad (i = 1, 2, \ldots\ldots m)$$

with $x_i \geqslant 0 \quad (m < n)$

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1. Nemchinov, "Mathematical methods in Economics" in Alec Nove (ed), Use of Mathematics in Economics, (London 1965), p.15.

where C_j = Coefficients of the objective function, the nature of which is determined by the selected optimality criterion.

a_{ij} = Input coefficients of production showing use of resource i per unit of product j.

X_j = Volume of output of product j.

b_i = Available quantity of production resources i.

The inqeuality implies that no more of outputs X_j (j = 1 ..... n) can be produced than the available resources b_i (i = 1 .... m) permit. The model as formulated assumes the multi-variant use of production resources b_i. For each variant there is a corresponding set of outputs X_j, which also determines the structure of production. The optimum variant of the plan is that variant (X_1, X_2 .... X_n) in which the extreme (maximum or minimum) value of the optimality criterion (objective-function) is achieved, given that the inequality conditions or plan constraints are satisfied.

An intrinsic part of this problem is a set of valuations which emerge for production resources and products reflecting the objective function and its constraints. This set of valuations or 'shadow prices' is obtained by solving what is called the dual of the primal problem outlined above. The dual to the above primal problem can be formulated as :

The task is to minimise the objective function

$$\sum_{i=1}^{m} b_i p_i \longrightarrow \text{min.}$$

subject to

$$\sum_{i=1}^{m} a_{ij} p_i \geqslant C_j \qquad j = (1,2, \ldots\ldots n)$$

with $p_i \geqslant 0$

where p_i is the dual or the shadow price of the production resource i.[2]

Mathematically it has been proved, that for an optimal solution the objective functions of the primal and dual coincide :

$$\sum_{j=1}^{n} c_j x_j = \sum_{i=1}^{m} b_i p_i$$

In his original work, Kantorovich pointed out that an increase in efficiency can be achieved in two ways. One way is by using new technology, new machines and raw materials. 'The other way — thus far much less used - is improvement in the organisation of planning and production. Here are included for instance, such questions as the distribution of works among individual machines of the enterprise or among mechanisms, the correct distribution of orders among enterprises, the correct distribution of different kinds of raw materials, fuel and other factors.'[3]

The method of linear programming, argued Kantorovich, was relevant to raising efficiency in the second way i.e. by reallocating resources between existing technologies and eliminating waste. This distinction between two ways of raising efficiency in production, subsequently emphasized by two other Soviet economists Gerchuk and Vainshtein, was

2. The details about the primal and the dual and their interrelationship can be had from W.J. Baumol, Economic theory and Operations Analysis.

3. Kantorovich, "Mathematical Methods of Production Planning and Organisation", in Alec Nove (ed), n.1, p.225.

an extremely useful one and it enabled Kantorovich to delineate the areas where its application could bring about useful gains in efficiency - production scheduling, the organisation of transport, the ~~uttering~~ cutting of sheets of materials, the utilisation of arable land etc. Ever since linear programming has been applied in areas pointed out by Kantorovich, both inside and outside the Soviet Union, and its application has led to a more effieient utilization of resources.

II

APPLICATIONS

It was only after the discussion on the use of mathematics in economics in the 1950's that application of linear programming to planning problems began. In 1958 and 1959 the institute of com plex transport problems carried out a number of experiments in working out least cost plans for the movement of freight by rail and lorry. In 1967, TSEMI together with the State Committee on material technical supply of the Council of Ministers of the USSR solved over 500 problems concerning optimization in transportation of supplies to customers. As a result it was possible to reduce freight turnover by 2,433 million ton-kilometres.[4]

Experiments have been made in the field of agriculture also. A study carried out at the All-Union scientific

4. N.P. Fedorenko, "Question pertaining to optimization of the growth and location of production", Problem of Economics, Vol.XI, No.9, Jan. 1969, p.15.

research institute of Agricultural economics (VNIIESKH) estimated that the better use of resources in terms of more intensive specialisation and concentration of production in places having the most favourable natural and climatic conditions, would increase gross agricultural output by 3-3.5 billion roubles in RSFSR alone.[5]

The most extensive use of linear programming in USSR has been made in optimising the development and location of individual sectors of industry. This entails a correct selection of variants for reconstruction and enlargement of existing enterprises, for determination of the optimal product mix for the sector, for construction sites for new enterprises, for the best size of enterprises and for their specialisation and cooperation, for the best scheme for the delivery and transportation of goods and raw materials etc. The first attempt to draw up an optimal sectoral plan was made in 1961 for the optimum fuel balances of the USSR for 1980.

An optimal plan for the location of the cement industry for the period 1966-70 meant a saving of about 75 million rubles (or 14 per cent) for capital investments and 96 million roubles for current inputs. Similar calculations have been made for 1975 and 1980.[6]

A plan for the development and location of RSFSR coal industry for 1966-70-75 was optimised in terms of

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5. *Ibid.*, p.15.

6. N.P. Fedorenko, *Optimal Functioning System for a Socialist Economy*, Moscow 1974, p.81.

66 consumer regions and 20 coal areas. The optimized plan helped to save about 13% on capital investment which worked out to 100 million rubles. Similar programming exercises for many industries have resulted in elimination of substantial waste.[7]

The extent to which programming is being used in economic calculation can be gauged from the fact that in 1966 optimization calculations were started for over 20 major sectors, whose capital investments added up to over a half of the total capital investments in the Soviet economy. In recent years the number of sectors for which optimisation calculations are being carried out has crossed hundred.[8]

A major use of linear programming has been in the sphere of calculating 'hire valuations' for different factors of production, reflecting their relative scarcity, and serving as guides to a more efficient allocation of resources. Shadow prices derived from a linear programme have formed the basis for evaluation of rent payments for the use of land and natural resources, of a charge for the use of capital goods etc. Such payments were introduced as part of the reform drive towards a more efficient allocation of resources.

Some of the major applications of linear programming in Soviet planning, as they have been actually applied in planning practice will be described in detail below :

<u>Application in Soviet Transportation</u> :

Finding the optimal variant for assignment of consumers

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7. See <u>Ibid</u>., pp.81-82.
8. <u>Ibid</u>., p.82.

to suppliers is a special case of one of the typical and most thoroughly elaborated problems of linear programming, the 'so-called transport problem'.[9]

The problem is amenable to a very simple formulation. Let there be n suppliers and m consumers. Denote the amount of freight that can be delivered by supplier i as a_i ($i = 1,2, \ldots, n$) and the requirement of consumers j as b_j ($j=1,2,\ldots, m$). Let x_{ij} be the flow of freight from supplier i to consumer j, and C_{ij} as the cost of shipment per ton of freight.

Then the objective function requires that total costs of transportation be minimized :

i.e.
$$\sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} X_{ij} \longrightarrow \text{Min}$$

subject to the constraints :

$$\sum_{j=1}^{m} x_{ij} = a_i \quad (i = 1,2,\ldots\ldots n) \longrightarrow (1)$$

i.e. for each supplier, the total of freight assignments which he supplies to all the j consumers ($j = 1 \ldots\ldots m$), should be equal to the total of freight resources that he can supply.

and
$$\sum_{i=1}^{n} x_{ij} = b_j \quad (j = 1 \ldots\ldots m) \longrightarrow (2)$$

i.e. for each consumer, the total shipment of freights by all suppliers should equal his total requirements.

9. See A. Kaplan, "The Application of Linear Programming methods in Soviet Transportation", Problems of Economics, June 1962, Vol.V, No.2.

Optimising the Structure of Production

Linear Programming is being extensively used in this sphere, especially for sectors producing substitute products. This problem deals with optimising the production of plastics.[10] The problem was based on the the assumption that within the planned period 1971-75, different variants for the development of the sector were possible, of which the variant giving the most efficient use of plastics would be selected.

Seventeen types of plastics were analysed. Let the index i stand for types of plastics from 1 to 17, and j stand for 98 lines of use i.e. sectors using plastics. Then x_{ij} is the unknown increment of consumption for each i plastic on any j line of use. x_{ij} cannot exceed the total requirements of plastic i in sector j i.e. Y_{ij}. Further, there is a lower limit to consumption set by the level of deliveries L_{ij}, already reached before the start of the planning period.

Then, $x_{ij} \leq y_{ij} - L_{ij}$ .... (1)

i.e. the increment in consumption x_{ij} is constrained by y_{ij} and L_{ij}.

The next constraint is set by capital investments. 'C' is the total fund available to the plastics industry for capital investment. If C_i stands for capital investment

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10. Given in Federenko, n.6, pp.91-97.

required per ton of production of plastic i, then :

$$\sum_{i=1}^{17} \sum_{j=1}^{98} c_i \; x_{ij} \leqslant C$$

i.e. in order to increase the output of all the types of plastics for all the consumers the sector cannot use capital investments (C) more than it has been allotted by the Gosplan.

Another condition is introduced by the requirement that all the capacities for plastic production existing at the start of the planning period be utilized. If the capacities are represented b_i. Then :

$$\sum_{j=1}^{98} x_{ij} \geqslant b_i$$

i.e. all the plastics which can be produced with the use of these 'old' capacities must be fully used.

Finally, as in the case of capital investments, only a limited quantity of scarce raw materials can be allocated for the developmental needs of the sector. Let k stand for the type of a scarce resource ($k = 1,2, \ldots..$), and R_k stand for the total availability of resources K. If r_{ik} stands for the per unit input of resource k into one ton of plastic i, then :

$$\sum_{i=1}^{17} \sum_{j=1}^{98} x_{ij} \, r_{ik} \leqslant R_k$$

i.e. the inputs in the total increment of plastic production cannot be greater than the availability of each type of scarce resource, allocated to the plastic industry.

Next is the problem relating to finding an objective function. The efficiency effect of using a ton of plastic i in line j was determined in advance. If the efficiency index per ton of plastic i used in line j is a_{ij}, then the objective function is :

$$\sum_{i=1}^{17} \sum_{j=1}^{98} a_{ij} x_{ij} \longrightarrow \text{Max.}$$

i.e. maximize that assortment of output of all plastics which will yield the maximum effect when used. The whole model can thus be written as :

$$\sum_{i=1}^{17} \sum_{j=1}^{98} a_{ij} x_{ij} \longrightarrow (\max)$$

subject to : $x_{ij} \leqslant y_{ij} - L_{ij}$ —— (1)

$$\sum_{i=1}^{17} \sum_{j=1}^{98} c_i x_{ij} \leqslant C \text{ —— } (2)$$

$$\sum_{j=1}^{98} x_{ij} \geqslant b_i \text{ —— } (3)$$

$$\sum_{i=1}^{17} \sum_{j=1}^{98} x_{ij} m_{ik}^{r} \leqslant R_k \text{ —— } (4)$$

The plastics problem was solved at the TSEMI together with the USSR ministry of the chemical industry for the 1971-75 plan. The optimization of the output structure of the plastics and its most rational allocation among the consumers, increased the total effect by 300-400 million rubles, with the same level of capital investments.

<u>Optimal Production Scheduling of Rolling Mills and Tube Mills in the Steel Industry</u>

The problem arises during the course of working out the production plan in consonance with the supply requirements. As part of the planning supply, Soyusglavmetal once the quotas have been finalized, has to work out attachment plans and production schedules in such a way that all the orders are satisfied and none of the producers receive an impossible plan.

Before the application of Linear Programming the ~~programming~~ problem was solved by production schedulers, who after receiving the orders from the consumers, placed on each order the number of the supplier plant and the number of the mill, keeping a file on each mill so as not to overload them. The production scheduler started work with a preliminary plan of mill loading, setting constraints of 'not more than N tons' type, incorporating certain types and sizes. In this traditional method, there was no guarantee that the attachment plans and production schedules worked out in this way were optimal.

Kantorovich and Gorstko,[11] using linear programming, designed the following model for optimum production scheduling

11. See Kantorovich, "The Best Use of Economic Resources", (Oxford 1965). Appendix I also given in Ellman, <u>Soviet Planning Today</u>, (Cambridge 1971), pp.164-170.

in the steel industry :

Output of n products, in the given assortment (k_1 ——— k_n) is to be distributed among m producing enterprises to obtain optimal results.

Let x_{ij} stand for share of the working time of the i^{th} enterprise devoted to producing the j^{th} product and a_{ij} for production possibility of the i^{th} enterprise for the j^{th} product per unit of time.

$(i = 1 ——— m), \quad (j = 1 ——— n)$

It is required to determine the proportion of time of each enterprise devoted to the production of each output in such a way as to maximise the volume of output given the assortment plan.

Thus, the objective function is

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij} x_{ij} \longrightarrow \max. \qquad (1)$$

subject to the following constraints

$$\sum_{j=1}^{n} x_{ij} \leq 1 \qquad ——— \qquad (2)$$

i.e. for each enterprise, the total time spent in producing the products cannot exceed the time available :

$$Y_j = \sum_{i=1}^{m} a_{ij} x_{ij} \qquad ——— \qquad (3)$$

(where Y_j = total output of good j)

i.e. the output of each good ~~xx~~ is the sum of the output of all the enterprises.

$$Z = \min_j \frac{Y_j}{K_j} \qquad \text{———} \quad (4)$$

i.e. the assortment plan is satisfied, and the non-negativety requirement :

$$x_{ij} \geqslant 0 \qquad \text{———} \quad (5)$$

The optimal plan would be characterised by the existence of shadow prices (given by the dual) q_1 ——— q_n for the outputs (or more precisely for the work involved in manufacturing them) and d_1 ——— d_m for the working time of the enterprises, such that $q_j a_{ij} = d_i$ if $x_{ij} > 0$.
(i.e. if the i^{th} enterprise produces the j^{th} product, then the shadow price received per unit of time for the product is equal to the shadow price of each unit of the enterprise's time).

$$q_j a_{ij} \leqslant d_i \quad \text{if} \quad x_{ij} = 0$$

(i.e. if the i^{th} enterprise does not produce the j^{th} product in the optimal plan, then the shadow price of the output which it would have been possible to produce per unit of time at that enterprise does not exceed the shadow price of a unit of time on the i^{th} enterprise).

$$q_j = 0 \quad \text{if} \quad Y_j > K_j Z$$

i.e. if the output is produced in excess of requirement then its shadow price is zero.

$$\sum_{i=1}^{n} x_{ij} = 1 \quad \text{if} \quad d_i > 0$$

i.e. if the shadow price of a unit of time at any enterprise is positive then the enterprise is fully occupied.

Optimal production scheduling was first applied to the tube mills producing tubes for gas pipelines, a commodity scarce in the Soviet Union. The optimal production schedule gave an additional output of 60,000 tons of tubes and a reduction in transport costs of about 15 percent, compared with the production schedules and attachment plans worked out by the traditional methods.[12]

Optimal Planning of the development and location of Industries

A major field for the application of linear programming to improving the methods of economic calculation has been in working out of optimal plans for the development and location of industries. The following problem was solved for the optimal development and location of enterprises for the mining and processing of coking coal.[13] The model optimizes not only the mixing, concentration and transportation of coal, but also the mix at chemical coking plants and metallurgical mills.

The development and location of coal mining at 230 operating and 60 projected pits and quarries in four basins were optimised, with some pits extracting simultaneously two or three grades of coal. The total number of coal grades was 15, with each grade differing in thermal capacity, quality and ash and ~~xxx~~ sulphur content. There were 27 consumer plants for which a total of 253 mixes were worked out.

12. Ellman, *Ibid.*, p.165.
13. Fedorenko, n.6, pp.97-102.

Among the various aspects considered were the following : where were the new coal concentration plants to be built, what coals they were to concentrate, which consumers were to be linked up with which pits and concentration plants, who was to get the concentrate, who ordinary coke, etc.

The model took account of the differences in the technical and economic indicators of the mining and processing of coals for coking, which may arise due to influence exerted by differences in mining geological and other natural conditions in the coal basins and coal fields, The techniques and technology of coal mining, its concentration and coke firing. Account was also taken of the different periods of construction for the various pits and a number of other problems.

In order that due consideration be given to the above factors, the inputs were calculated as weighted annual coverages. As the model is complicated and xx involves the usuage of cumbersome notation, the full mathematical presentation is given in the Appendix to this chapter. Here only a brief description of the constraints and the objective function is given.

Four sets of constraints were devised :

The first set related to constraints for requirements, the second to constraints for raw material deliveries to plants. The third set comprised of constraints for resources, and, finally, the fourth set dealt with constraints for In-out balance for ordinary coal and concentrate for any grade_point.

The criterion of optimality was formulated so as to minimize aggregate capital and running input for coal mining, production of coke concentrate, transportation to the points of consumption and the use of coals in coking and blast-furnace production (for details see Appendix).

The problem involved roughly 500 equations and 2,000 variables. A significant amount of savings were made through the optimisation exercise. The savings on capital inputs, as compared to the earlier scheme came to 150 million roubles, or 20 per cent. Annual savings on current production inputs equalled 98 million rubles including 40 million rubles on improvement of grade-mix. However, there was an increase in the average distance of coal transportation from 771 to 921 kms., arising mainly from the use of low-cost coal at a particular mine at Kuznetsk. This lead to an increase in transport inputs by 24 million rubles a year, but this was more than compensated by the savings on current production inputs. The exercise also lead to important qualitative conclusions concerning the change of development rate in some coal basins, changes in zones of coal deliveries, changes in mix, etc.

Payments for natural resources

Traditionally, Soviet enterprises have not had to pay for the use of land or natural resources. Rent payments for the use of scarce natural resources were introduced as part of the reform, and currently this principle is drawing increasing attention in Soviet Planning. The need for such payments can be illustrated by the following simple example :[14]

A farm has three pieces of land of varying fertility. The best piece size 200 hectares, can yield 25 centners per hectares. The middling one, size 500 hectares can yield 20 centners per hectare, and the worst piece of land size 400 hectares — yields 15 centners per hectare. Labour costs per hectare on each piece of land are 3 man days, and the resources available are 3000 man days. For simplicity it is assumed that the non-labour resources (seed, fertilizer, machines etc) are used in equal quantities per hectare on all three pieces of land, and are available in abundance and do not limit production. The data can be represented by the table.

TABLE : RESOURCES, COSTS, OUTPUT

Resources	Expenditure/unit of output			Volume of Resources
	Best land	Middling Land	Worst Land	
Land. Best (hectares)	0.04			200
Land Middling (hectares)		0.05		500
Land Worst (hectares)			0.07	400
Labour (man days)	0.12	0.15	0.2	3,000
Output	1	1	1	

Each column indicates the inputs necessary to produce 1 centner of wheat on that type of land. For example, the second column indicates that to produce 1 centner of wheat on the middling land requires 1/20 = 0.05 hectares of land, and

14. For this example, see Ellman, n.11, pp.35-7.

3/20 = 0.15 man days. In order to maximize output, the optimal solution is to use 600 man days on best land, 1500 man days on the middling land, and 900 man days on the worst land. Total output is 19,500 centners and 100 hectares of the worst land are superfluous.

Solving the dual problem, the shadow prices are, for labour 5, for the best land 10, for middling land 5 and for the worst land 0.

Differences in the fertility of land results in the fact that varying quantities of labour are expended per unit of output, at the same time that the expenditures of labor per hectare are identical. Utilisation of the middling land rather than the worst saves 0.05 man days per centner of output, and per hectare the saving is 1 man day. The use of a hectare of the best land saves two units of labour in comparison with expenditures on the worst land, and the shadow price of 1 hectare of the best land is twice the valuation of 1 man day of labour.

Hence, the shadow prices of pieces of land of different fertilities reflect the saving of labour resulting from production on the best and middling pieces of land rather than on the worst piece. With identical expenditures of labour and the means of production per unit of sown area, the shadow price indicate the quantity of differential rent caused by differences in the fertility of the pieces of land.

In our example, if we let the valuation of 1 man day of labor be equal to 5 rubles, then the differential rent from 1 hectare of the middling land is 5 roubles and from 1 hectare of best land, 10 roubles. Including differential rent in the valuation of output equalizes cost per unit of output on pieces of land of different fertility.

The direct calculation of differential rent helps the solution of a number of problems. It opens up the possibility of fixing rent payments to the state for these enterprises which use relatively better natural resources and land. This creates real equality in the conditions of enterprises in agriculture and mining regardless of differences in their natural endowments. The payment of rent is a stimulus for the rational utilization, better maintenance, and safeguarding of natural riches. An objective index for the comparative economic evaluation of land, and also raw material deposits, forests and other natural resources is created.

III

An Appraisal

All the models showing applications of linear programming in optimal planning, outlined above, suffer from various limitations, some specific to a particular exercise and others which are universal in character i.e. they would arise in any application of linear programming. We woubd undertake a very general discussion of the various limitations and not go into the specific details relating to each of our models. For the sake of precision, the limitations have been classified under suitable headings. Appropriate references will be made to our models, in order to illustrate the kinds of problems which may arise when linear programming is used in a particular area.

1) <u>Problems relating to information</u>

The efficacy of the results given by a technique would always be determined by the accuracy of the initial data fed into the model based on the technique. Linear programming is a relatively new addition to the methodology of planning. It has not replaced the traditional methods of calculation. The book-keeping and statistics which provide the data have been evolved according to the requirements of traditional planning and are more or less closely tailored to satisfy them. The use of data so collected, may result in inaccuracies, and in some cases may even be unsuitable for use by methods of linear programming.

For instance, for an optimal solution of the transport problem set out in the previous section, there is a definite problem relating to validity of the norms used by the traditional methods. The traditional calculation methods in transport required indices of cost in terms of average expenditure. Linear programming requires more concrete forms of cost calculations, for individual divisions, categories of freight, directions of movement, and types of rolling stock. This in turn requires cost computed not in terms of average expenditures for the system, but according to data for the particular divisions and ~~[illegible]~~ freight yard serving the given section of line. In this way it is possible to take account of only the expenditures which depend upon 'movement', and isolate and omit "numerous non-dependent" costs, which are difficult to allocate to specific freight movements", and which "remain unchanged no matter which version of the plan is employed".[15]

Successful application of linear programming methods also depends on the flow of information. For optimum current planning, prompt and accurate preliminary information is of the greatest importance. In most of the industries, a large proportion of orders are changed between the submission of orders and the delivery. The problem is quite serious, mainly for the reason that enterprises have to send in orders for inputs before they are aware of their production plan. In such cases the traditional methods offer more scope and room for adjustment. For example, in our production scheduling problem, the production schedulers have detailed knowledge of the real needs of the consumers which may be more reliable than the information available to the compilers of optimal plans. In practice there is always scope for some substitutability in requirements and to some scarce products the production schedules can suggest acceptable alternatives to the consumer in a way not open to the compilation of 'optimal' plans.

Finally, it need be mentioned in this context, that to deal with the huge size of the calculations involved in

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15. A. Kaplan, n.9, pp.30-31.

general, much of the information is aggregated, leading to aggregation errors.[16] At times, many important factors may be neglected, for example, in production scheduling for steel industry, the cost of transporting billets from which the required production is rolled is often not taken into account.

2) <u>The Problems relating to the formulation of an Optimality Criterion</u> :

The most employed optimality criterion is maximization of the local optimality indicator, the profits, or conversely minimisation of inputs. Now maximization of profits may not yield the product mix socially desirable, for instance, a better quality but relatively more expensive product may not be produced. Similarly a product using chepper inputs, but socially irrelevant may be produced. In general, a local optimality ~~xxxxxxx~~ criterion may ignore the costs and benefits which accrue to other economic units i.e. ignores externalities.

The problem gets magnified when an objective function relates to interaction between two sectors. The example on plastics industry illustrates this very well. In this case the objective function $\sum_{i=1}^{17} \sum_{j=1}^{98} a_{ij} x_{ij} \longrightarrow (max)$ does not pertain to the plastics sector alone. Whereas,

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16. The steel industry receives more than 1000000 orders, involving 60,000 users, has more than 500 producers, issuing tens of thousands of products every year.

maximization of the function would lead to a certain combination of x_i's (i.e. types of plastics), it also relates to the efficiency effect (a_{ij}) of the plastics in sectors. (j=1 ——— 98). Here an assortment which leads to maximum efficiency effect of use of various types of plastics in the consuming sectors, may not be the most profitable assortment for the plastic industry itself.[17]

The objective function of the type used in our example of optimising the development and location of coal industry requires the conversion of units of transport inputs into units of measurement employed in measuring coke. i.e. in terms of tons of concentrate. (See Appendix). This is bound to lead to measurement errors. In cases where the input to be reduced in this manner is heterogeneous, aggregation errors will also result.

A major limitation is introduced when sectoral optimisation is sought in the absence of an optimal plan applying to the economy as a whole. An objective function may suffer from various shortcomings, as the resources in a sectoral problem are not considered at valuations which are optimum for the economy as a whole i.e. the inputs, raw materials etc. used in the sector for which the optimal plan is being worked out are not determined by optimal prices; similarly the consumers of this sector's products may not be working at prices

17. A major argument against using profits as a local optimality criterion is that it might yield results socially undesirable.

yielding optimal results. The net result would be a failure to take account of extremal problems in isolation from each other and from the national optimal plan.

3. Limitations Introduced by simplifying assumptions

All the linear programming models described by us treat the activity level as continuous variables (activity implies an economic process like production, investment, imports etc.). Divisibility can only be assumed if the product involved in the activity is itself fully divisible. In most of the cases products are not divisible. 'The level of investment activities could be regarded as perfectly divisible if the new capacities established as the result of these activities were themselves divisible at will. This is, of course, never the case'.[18] Mx It is impossible to install 1/3 or 7/10 of a machine. Significant distortions can be introduced in the cases of industries where very large and costly units of machinery are involved in certain processes and technological phases, for instance, electric power generation, the iron and steel industry etc. This limitation is particularly pertinent in the case of Soviet Union as the scale of production is generally very large. There are so-called discrete programming methods, but as yet they've not been applied in Soviet planning. The discrete procedure is very awkward from the computational

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18. Kornai, Mathematical Planning of Structural Decisions, (Amsterdam 1965), See the discussion on pp.86-87.

point of view. It implies a predetermined range of variants for the capacity and structure of an enterprise. For example, capacity of polyethylene installations is preset at 30,000, 60,000 and 120,000 tons etc. a year. 'With the approach, however, the optimal variant may not be among the variants formulated in advance'.[19] Both the objective function and the system of constraints in the models are linear. The linearity assumption implies constant returns to scale and constant input and output prices. This requires that costs and profits rise precisely in proportion with the level of output. This is a highly simplifying assumption. Normally, and especially in large-scale production, technological diminishing and increasing returns arise in the production process. The cost curves are, in general, U-shaped and not straight lines. The profit functions associated with U-shaped cost curves are inevitably non-linear. Investigations have revealed that even a very slight degree of non-linearity can cause a linear programming calculation to yield answers which differ substantially from the true optimum. Moreover, the linear programming calculation can easily produce a solution worse than that which serves as the initial point for the

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19. Fedorenko, n.6, p.88.

calculation.[20] Some degree of non-linearity is the rule and not the exception in economic programming problems.

The optimal shadow prices, which result from a linear programme necessarily imply a marginal cost system of pricing. Dobb has correctly pointed out that a case for universal application of marginal cost as a criteria for pricing is very weak. Only in some case, can marginal cost prices yield appropriate results.[21] The universal significance attached by Kantorovich to his 'objectively determined valuations' or shadow prices based on a linear programme, has been severely criticised by Nemchinov.[22] According to Nemchinov, these valuations cannot be regarded as universal equivalents for the substitution of some resources by others, and can only play 'a subsidiary role of valuations of shortages and scarcities of resources'. Further, 'the valuations are for purposes of allocation. They cannot be regarded as criteria for production and they must not be treated as costs'.[23] The role of prices

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20. W.J. Baumol and R.C. Bushnell, "Error produced by linearization in mathematical programming", Econometrica 1967. Their investigations have shown that in over sixty percent of the sampled cases the linear programming calculation yielded less than fifty per cent of the true maximum profits and that in fifty eight per cent of the cases it led to absolute losses. In more than eighty per cent of their randomly selected examples the linear approximation gave results poorer than the randomly selected initial point.
Also see Kornai, n.18, for a discussion on non-linear cost functions and their linear treatment (Chapter 7).

21. M. Dobb, 'Marginal Cost revisited', in Welfare Economics and Economics of Socialism, (Cambridge, 1971).

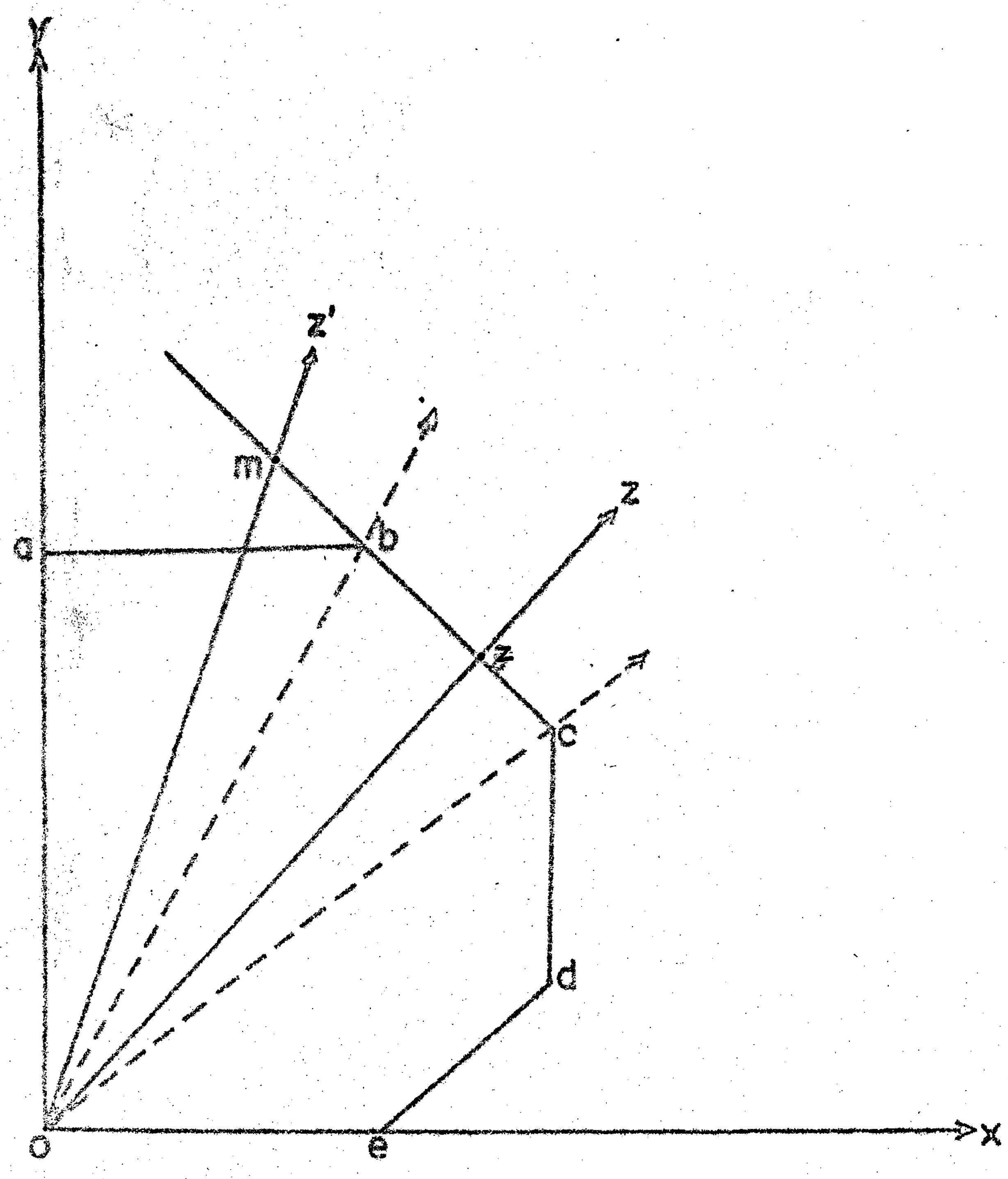
22. Nemchinov, editorial preface to Kantorovich's book, n.11.

23. Ibid. pp. xi. Also see M.Dobb, 'Kanterovich on optimal planning and prices' in Papers on Capitalism, Development and planning, (Bombay, 1967).

given by optimal planning and its relation to socialist pricing and the operation of the law of value under socialism, has been a subject of intense and wide-ranging debate, and it is not possible here to recapitulate the entire discussion on the subject. All that need be said is that the prices attached with linear programming can be undesirable.

Shadow prices lead to a further difficulty related to what is known as stability of the shadow prices. An optimal plan having a definite assortment of products to be produced, produces a definite structure of shadow prices associated with this particular assortment. That is, shadow prices and the structure of output are simultaneously determined. These shadow prices remain stable as long as the assortment varies within the two corners of the linear constraint on which the optimal plan lies, but if the assortment changes beyond that, the shadow prices become irrelevant. This can be illustrated diagrammatically, with a two goods case, X & Y; with ab, bc, cd, de being the linear constraints.

The arrow Z shows the assortment vector of products X & Y. The optimum result is given by point s on the linear constraint bc. If Z changes between b & c, then the shadow prices remain stable over bc and there is no problem. But if Z changes to Z', we land into difficulty. The old shadow prices given by the slope of the bc show


Y
z'
m
a
b
z
z
c
d
o
e
X

that plan m is feasible, whereas m is clearly not feasible as it lies outside the feasibility region abcde o. Once we are on assortment vector Z', the old shadow prices become irrelevant and new ones emerge. This is a problem inevitably linked with the simultaneous determination of outputs and prices in linear programming and can be a major limitation in its application to planning.

As pointed out previously, the linear programming method as applied above assumes a static technology. It may happen that the long-run savings resulting from technical progress are substantially greater than efficiency resulting from the use of this method. Further, it is possible that more short-run savings can be generated by improving the way the economy functions (e.g. a reduction in the construction and running in periods for new plants) than by programming calculations.[24]

These are some of the major limitations, though certainly not all, which restrict the use of linear programming as a tool of optimal planning. Nevertheless, it would be naive to overemphasise the weaknesses. The application of linear programming has revealed significant potential for a more efficient use of resources, as illustrated in our examples. Thus it has a decisive edge over the traditional methods of calculation. 'As a practical activity optimal planning is concerned with obtaining bad answers to questions to which worse answers are obtained by other methods.'[25]

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24. Ellman, n. p.176.

25. *Ibid.*, p.177.

So far we have presented linear programming as an optimizing technique applicable to particular areas, as developed by Kantorovich in 1939. Subsequently, Kantorovich reinterpreted linear programming as a model of national economic planning, both current and perspective. Many economists, mainly cyberneticians, the TSEMI and some other similar institutes, have since been arguing for an optimally functioning socialist economic system. Most of their arguments and conclusions derive from linear programming as an instrument of constructing national economic plans.

Application of linear programming at the level of the economy as a whole, would entail, in addition to the ones we have already outlined, serious complications. The task would invite a colossal amount of data collection and computation. As a Soviet economist has commented : "A huge number of variables, and interrelations of various kinds connecting them to one another, place before us a barrier unsurmountable at the present time".[26] It would be difficult to take note of the various interrelations among the different branches of the economy. The complexity of these interrelationships would produce non-linearities of a degree unsuitable for linear approximations. With a constantly expanding economy and an ongoing 'scientific and technical revolution' these complexities will multiply at a rate beyond the scope of a method like linear programming. Veinshtein correctly argues

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26. A.L. Veinshtein, "Notes on Optimal Planning", in Nove and Nuti, <u>Socialist Economics</u>, (Penguin, 1972), p.470.

that for the purpose of drawing up a national plan, methods of linear programming are inadequate. "They must be supplemented with other forms of mathematical programming. The methods of linear programming have their own boundaries, even if sufficiently wide, but they are not the omnipotent mind of Laplace".[27]

Apart from the aforesaid mathematical limitations of the technique, the major problem is the formulation of an objective function, the optimality criteria. It is difficult to perceive of an optimality criteria expressing the convergence of the conflicting interests of the various groups and strata in Soviet society. Soviet planners and economists have intensely debated the choice of an optimality criterion, but as yet no conclusion seems to be in sight.

Not surprisingly, the construction of an optimal national plan in the Soviet Union, using linear programming, has not progressed beyond discussion and the printed word. The probability of the happening in the near future, is not very bright. (The Hungarians have tried using a standard linear model to construct a national plan model for 1966-70. The actual plan of course was not based on this model alone. It was prepared by a simultaneous use of traditional methods and programming. For the sake of illustration, the details are given in the appendix to this chapter).

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27. <u>Ibid.</u>, p.474.

APPENDIX TO CHAPTER III

I

Optimal Development and Location of Enterprises for the mining and processing of coking coals

CONSTRAINTS :

1. Constraints for requirements

$$\sum_{r=1}^{S_{jr}} x_{jr} \geqslant A_j \qquad (j = 1, 2 \text{———}, n)$$

At each consumer plant the total mix variants included in the optimal plan ensure fulfillment of annual production programme.

Here :

- j —— index of consumer plant
- r —— index of mix variant
- S_{jr} —— number of mix variants at plant j
- x_{jr} —— annual mix output at plant j
- n —— total number of plants.

2. Constraints for raw material deliveries to plants

$$\sum_{r=1}^{S_{jr}} a_{jrl} \; x_{jr} - \sum_{i \in I_k} x_{ijl,k} \leqslant 0$$

Complete satisfaction of consumer plant with deliveries of concentrate of required grades from all suppliers is obligatory.

Here :

- a_{jrl} — share of l grade coal in r mix variant at plant j.
- i — index of supplier.
- I_k — set of suppliers.
- $x_{jrl,k}$ — delivery of l grade concentrate by supplier i to plant j.

3. Constraints for resources.

$$x_{fl,k} + x_{fl,p} = M_{fl,ob} \quad (l = 1,2, \ldots\ldots, k) \quad (f = 1,2, \ldots\ldots, p)$$

For operating pits which must be included in the plan, total deliveries are equal to fixed volume of output

$$x_{fl,k} + x_{fl,p} \leqslant M_{fl} \quad (l = 1,2, \ldots\ldots\ldots, h) \quad (f = 1,2, \ldots\ldots\ldots, p_1+1, \; p_1 + 1 + 2, \ldots\ldots, p)$$

At pits whose obligatory inclusion in the plan is not provided total deliveries must not exceed maximum allowable volume of output.

Here :

- f — pit or quarry index
- p — total number of pits
- p_1 — number of operating ~~pits~~ pits for which obligatory inclusion in the plan is provided.
- $M_{fl,ob}$ — volume of output of l grade coal at pit f for which obligatory inclusion in the plan is provided.
- M_{fl} — Maximum possible volume of output at pit whose obligatory inclusion in the plan is not provided.

$x_{fl,k}$ — quantity of l grade coal extracted at pit f and concentrated at basin d.

$x_{fl,p}$ — the same for coal concentrated at chemical coking plant.

4. Constraints showing In-Out balance for ordinary coal and concentrate for any grade-point.

$$\sum_{f \in F_i} x_{fl,p} - \sum_{j=1}^{n} x_{ijl,p} = 0$$

For each grade-point total deliveries of ordinary coal from pits are equal to total deliveries of ordinary coal to all plant concentration factories.

Here :

i — index of grade-point supplier (point of shipment of a given grade of coal)

F_i — set of pits adjacent to grade-point i

$x_{ijl,p}$ — delivery of ordinary l grade coal of grade-point i to plant j.

<u>Objective function</u> :

Since the objective function reflects the total inputs for the mining, concentration and transportation of coking coals, the reduction of all the transport inputs to a single unit of measurement (one ton of concentrate) requires that the sum-total of these inputs for flows of ordinary coal should be multiplied by corresponding corrective coefficients.

The function is :

$$\sum_{f=1}^{P} z_f \sum_{l=1}^{L} (x_{fl,k} + x_{fl,p}) + \sum_{d=1}^{L} z_d x_d +$$

$$\sum_{j=1}^{h} z_j x_j + \sum_{i \in I_s} \sum_{j=1}^{h} \sum_{l=1}^{L} z_{ijl,p} \; x_{ijl,p} +$$

$$\sum_{i \in I_k} \sum_{j=1}^{h} \sum_{l=1}^{L} z_{ijl,k} \; x_{ijl,k} + \sum_{r=1}^{s_{jr}} z_{jr} \, x_{jr}$$

$$\longrightarrow \min.$$

There is need to minimize the total inputs for the mining and concentration of coal at 4 coal basins, concentration of coal at the plants, transportation of ordinary coal and concentrate and inputs connected with the selection of mix variants at the plant.

Here :

z	—	index of corresponding type of input
x_d and x_j	—	Volume of concentration respectively at basin d and at concentration factory j (or plant j)

II

A National Multi-Sectoral Programming Model for Hungary for the Five-Year Plan 1966-70

The national model was composed of forty sectors. A sector was defined as a productive and foreign-trading unit responsible for a definite range of products or services and obliged to supply to the rest of the national economy the products or services in question.

The individual sectors were generally responsible for several - six to ten, in some cases fifteen to twenty - product groups, aggregates composed of a variety of concrete products. In the following, the product aggregates will be called products. The economy-wide model contains a total of some 400 products.

The program obtained by means of the model constituted a complex investment, technical development, production, international financial, export and import plan.

The model contained a great number of constraints. The sector models were not autonomous, but related to one another by numerous links. From this point of view the constraints of the sector models were classed into two main groups, namely intrasectoral and inter-sectoral constraints.

The intrasectoral constraints regulated the 'internal affairs' of the sector. They included those of the technological equations which described the flow of products within the sector; the constraints of the sector's initial capital stock, initial capacities etc.; the individual export marketing constraints relating to the sector's products.

The intersectoral constraints, on the other hand, regulated the sector's 'external affairs'. They included all equations which described the flow of products between

the individual sectors (e.g. electric energy constitutes the output of the electric-energy sector and an input for all other sectors - The balance of electric energy must therefore be considered an intersectoral constraint for all sectors).
The same applies to the allocation of the resources which are being drawn upon by several sectors (e.g. the gross investment quota, the wage fund etc.).
The notation used was as following :

A_i — matrix of the coefficients figuring in the inter sectoral constraints of the i^{th} sector. (in the model i=1,2,......., 46 but for the sake of a more general formulation the model speaks of n sectors).

B_i — matrix of the coefficients figuring in the intra-sectoral constraints of the i^{th} sector.

U_i — Vector of the intersectoral constraint constants of the i^{th} sector.

b_o — Vector of the macro-economic bounds of the inter-sectoral constraints.

b_i — Vector of the intrasectoral constraint constants of the i^{th} sector.

C_i — Vector of the objective function coefficients of the i^{th} sector.

x_i — The program of the ith sector, including slack variables.

x — (x_1, x_2, ..., x_n) — national program.

x_i^{off} —— the official program of the i^{th} sector as worked out on the basis of traditional methods.

x^{off} —— the official program.

The calculations were to be carried out in two phases. In the first phase, each individual sector was to carry out its own programming project separately; in the second phase the sector models were to be linked up and combined into a single large-scale economy-wide model. The two phases were to be carried out in the following manner :

First Phase :

First, the intersectoral constraint vector U_i should conform to the official sector program x_i^{off}.

$$U_i = A_i x_i^{off} \quad - - - - - - (1)$$

Next, the intersectoral programme should satisfy the intersectoral constraints.

$$b_i = B_i x_i^{off} \quad - - - - - - - - - (2)$$

Should, in exceptional cases, this condition is not fulfilled, the official program is corrected, and this corrected program which satisfies condition (2) is used as x_i^{off}.

Then to determine the program x_i^*, the following linear programming problem is solved by means of an electronic computer :

$$\begin{cases} (a) & A_i x_i = U_i \\ (b) & B_i x_i = b_i \\ (c) & x_i = 0 \\ (d) & c_i x_i \longrightarrow \max ! \end{cases} \quad - - - - - - - - - (3)$$

Program x_i is called the 'dominant' sector program as it generally dominates the official sector program x_i^{off}, both x_i^* and x_i^{off} satisfy the conditions 3(a) to 3(c) ~~xxx~~ and at the same time the dominant program is considerably better than the official one from the point of view of the objective function 3(d). This objective function showed 5 to 15 per cent savings in the dominant sector programs as against the official sector programs.

By the end of the first phase, already at least two national programs are available, namely

$$x^{off} = x_1^{off}, x_2^{off}, \text{———} x_n^{off},$$

the official program of the national economy, and

$$\overline{x} = x_1, x_2, \text{———}, x_n$$

the conjunction of the dominant sector program obtained as a result of the calculations carried out in the first phase, as the solution of problems 3. In the following, $\overline{x}$ is known as the national program of the first approximation.

Second Phase :

Here the sector models are combined into a single large-scale national model. The following linear programming problem is considered :

$$\begin{array}{lllll}
\text{(a)} & A_1x_1 + A_2x_2 + \text{———} + A_nx_n & = b_0 & & \\
\text{(b)} & B_1x_1 & = b_1 & & \text{———(4)} \\
 & \quad B_2x_2 & = b_2 & & \\
 & \qquad\qquad B_nx_n & = b_n & & \\
\text{(c)} & x_1 = 0, \; x_2 = 0, \ldots\ldots, x_n = 0 & & & \\
\text{(d)} & C_1x_1 + C_2x_2 \longrightarrow \max ! & & &
\end{array}$$

The constraint vector of the intersectoral constraints b_o — can be determined, in a manner analogous to calculation 1, as follows :

$$b_o = \sum_{i=1}^{n} A_i x_i^{off} = \sum_{i=1}^{n} U_i$$

The following statements can now be made about the two national programs already known :

Firstly, both the official national program x^{off} and the national program of the first approximation x are feasible i.e. they satisfy conditions 4(a) to 4(c).

Secondly the national program of the first approximation $\overline{x}$ dominates the official national program : according to objective function 4(d) it is more advantageous than the latter.

In the second phase of the calculations the aim is to find a program which is more advantageous according to the objective function 4(d) than the one of the first approximation, i.e. which dominates the official program to an even greater extent.[28]

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28. See J. Kornai, "Mathematical Programming as a tool of Socialist Economic Planning", in Nove and Nuti, n.24.
Also see Kornai and Liptak, "Two-Level Planning", *Econometrica*, no.33, pp.141-69.

CHAPTER IV

C O N C L U S I O N

CONCLUSION

Soviet Union was the first socialist state to bring its means of production under state ownership. With the change in the property relations an objective basis was created for planning to emerge as an economic force. For the first time possibilities were created for the replacement of anarchy of production and allocation of resources through the spontaneous operation of the law of value in a market by a conscious control and guidance of the productive forces.

But that was about all. There was no methodology of planning to make use of these possibilities. The terrain as yet had been untraversed. Apart from some abstract theoretical formulations made by Marx and Engels in their writings on a social formation they were never to witness, there was absolutely nothing to guide the Soviet planners. They had to grope their way forward, learn from their experience and develop a methodology and techniques of planning which would guide productive activity in accordance with the economic laws of socialism.

Inevitably, as indeed it is in such matters, the terrain covered was an arduous one, marked by intense debates and controversies. Chapter one set out an historical overview of the problem of planning techniques, how they developed as the Soviet economy itself developed and how during the course of this development some techniques lost their earlier precision and had to be supplemented by new ones. This transition from old methods to new ones, the latter involving an increasing use of mathematics, proved to be a difficult one, took a long time and was accompanied by bitter polemics between the orthodox political economists and the new breed of cyberneticians and optimal planners. Some important issues concerning the political economy of socialism and the use of mathematical planning techniques were raised.

Chapter two examined whether the methods of material balances and input-output could help compile a consistent plan. None of the two techniques examined, it emerged, could solve the consistency problem. Where input-output really scored over material balances as a technique, was that it could be used for variant calculations. Since it also gave useful insight into the structure of the economy, it was a very valuable addition to the planner's kit. However, given the fact that technology does not permit compilation of input-output tables big enough to cover all products both input-output and material balances have to be used together.

In chapter three the way linear programming can be employed as a technique for optimal planning was discussed. Though linear programming certainly helps in improving the economic mechanism by way of a more efficient allocation of resources through eliminating waste, it does not guarantee an optimal allocation of resources. Moreover, the application of linear programming is limited to specific areas and compilation of an optimal plan for the economy as a whole is still a distant goal, which strictly speaking, is beyond the scope of linear methods and much more advanced techniques of non-linear programming are required for the purpose.

Our conclusions point out to the insufficiency of planning techniques to find an optimal plan, which is necessarily both consistent and optimal. What then, the question naturally arises, is the scope of these techniques and the use of other mathematical methods in planning?

The scope of planning techniques and use of mathematical methods in planning is always relative to the setting in which they are being used and in this sense is defined by the level of development of the economy. Development of the economy in turn is defined in terms of the development of the productive forces and the relations of production and, of course, the degree of correspondence between the two.

From the political economy of socialism, for the purposes of our analysis, we have two economic laws operating in a socialist economy. The operation of the first law requires, that, as opposed to competition and anarchy of production under capitalism, there is a planned, balanced and proportionate development of the economy. Xxx According to the second law, unlike the wasteful use of resources under capitalism, in a socialist economy there is the most efficient utilization of given resources and the maximum saving of labour in the various branches of production.

These two laws reflect our problems of consistency and optimality respectively. These laws will operate fully, only in a social formation which is a complete antithesis of the capitalist formation, in the sense that all the contradictions characteristic of the latter are completely abolished. Above all, production relations do not impose fetters on the productive forces, but are always helping them to advance rapidly. Such an antithesis to capitalism can only be communism, and socialism is only a transitory phase. Socialism abolishes private property, but does not abolish all social differentiation, which in turn implies existence of various groups with divergent interests. An optimal plan in a society with group interests is not feasible. It is feasible only when various local interests converge and are in consonance with the global interest defined in terms of the national economic plan. Thus, while socialism by abolishing private property creates an objective basis for the above two laws to become operative, they acquire their full force only under communism. In this sense strict conditions of consistency and optimality in planning can only be satisfied in the stage of communism. Under socialism plans can successively progress towards consistency and optimality as the development of productive forces and production relations imparts momentum to the above two laws.

Thus all their own limitations and shortcomings notwithstanding, the scope of planning techniques and mathematical methods in a socialist economy will be a function of the strength with which the two laws operate, this strength being determined, to repeat, by the level of development of productive forces and production relations.

Indeed, as the productive forces develop, one can say that planning techniques and mathematical methods and the technology and the instruments necessary to put them to use will themselves develop, and the science of planning itself will increasingly become more and more capable of producing an optimal plan. But this cannot be all. Development of planning methodology has to be accompanied by certain qualitative changes in the sphere of organisational structure, social relations and all those variables which can impose fetters on the development of the economy.

In sum, it can be said that the scope of planning techniques and mathematical methods is defined by their own development, and by the development of the quantitative and qualitative factors in the economy. In other words when planning techniques produce inconsistent or inoptimal results, the reasons for failure may lie elsewhere and not with the techniques themselves.

According to economists Nemchinov and Novozhilov[1] the main hindrance to optimal planning in the Soviet Union is the divergent interests of the controlling and controlled elements in the economy. Optimal planning requires that optimization be done not only with respect to quantitative factors but also with respect to qualitative factors. The

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1. Novozhilov, "The problems of developing the theory of optimal planning in the present stage", <u>Problems of Economis</u>, July 1971.

most important qualitative factor that requires utmost attention is the relation between the controlled and the controlling elements in the economy. Novozhilov contends that different forms of socialist relations and socialist organization of the economy produce different effects. The optimum variant of these relations and organization is that which produces complete agreement between the controlling and the controlled elements.

Disagreement and contradictions result from a one-way relationship viz. only the enterprises are accountable to the centre for any errors and omissions with respect to commands received from the centre, and the centre itself is not accountable for any disproportions it might introduce in the final version of the plan. This drives the enterprises to keep hidden reserves and underestimate their capabilities to meet the uncertainties introduced by the disproportions in the central plans. The central planners then plan from the achieved level because there are hidden reserves. Thus what we have is a vicious circle. Novozhilov pinpoints this one-way relationship between the planning bodies and the enterprises as the root source of all problems of the Soviet economy. He concludes that changes in economic levers cannot remove this contradiction and a thorough restructuring of the relationship between the controlled and controlling elements is required. These relations "must be based on mutual advantage and mutual responsibility".[2]

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2. *Ibid.*, p.7.

Taking the cue from Novozhilov, it can be said that mathematical techniques play a secondary role, and have a limited scope as far as optimization is concerned. The primary role is assigned to the qualitative variables described by Novozhilov. The insufficiency of planning techniques alone in optimal planning is illustrated by Novozhilov as follows :

" Due to the vastness of the national economic plan, its corresponding dual prices can apply only to a relatively small number of consolidated groups of goods. The process of breaking down these prices into prices of specific goods inevitably implies the existence of certain conditions. Therefore, price agreements between planning bodies and enterprises are needed not only to verify the optimality of planning prices (their capacity to coordinate interests), but to make substantiated breakdown of consolidated prices. Thus the plan targets must be made a plan order so as to adjust the system of economic levers to a point at which individual interests become compatible with general interests. Accordingly the plan order is a necessary means for optimizing the prices of individual goods.

Another consequence of coordinating the interests of the controlled and the controlling elements of production is an improvement in the composition of plan variants proposed from below, i.e. in the foundation of optimal planning. The level of effectiveness of the plans depends on the effectiveness of the initial plan variants and on the effectiveness of their combination, which satisfies constraints on requirements and on resources.

Mathematical methods of optimal planning are designated for the solution of the second problem, that of finding the most effective combination of plan variants. However, it is apparent that the level of effectiveness of an optimal plan arrived at in this way is determined by the quality of the initial material - by the composition of plan variants. After all, in elaborating the plan, consideration is not given to every possible variant of the plan decisions, but only to a very small part of them, because the elaboration of each variant requires a considerable expenditure of skilled labour. The composition of this part of planning elaborations depends on knowledge, on the organizational potential and, finally, on the interests of the production personnel. Mathematical planning methods do not directly influence this composition. But since the questions of the procedure for selecting initial variants goes beyond the purview of mathematical programming, one is reminded of the similitude between mathematics and a millstone that grinds up only what is fed into it. However, since the theory of optimal planning has until now concentrated its attention essentially on mathematical programming alone, the problem of improving those economic relations in which the composition of initial plan variants is developed has been neglected. Yet, at the present time, coordination of the interests of the controlling and the controlled elements of production probably conceals

<u>more reserves for the growth of a socialist economy than the application of mathematical programming when the previous relationship between the controlling and the controlled elements of the economy are retained.</u>[3] Thus, a necessary part of optimal planning is the optimization of its foundation : the process of seeking and elaborating variants of lower-echelon plans".[4]

Thus the main problem with optimal planning in the Soviet Union, says Novozhilov, is not solely because of adequacy or inadequacy of the planning techniques and mathematical methods but "because precise methods for optimizing the economy with respect to qualitative factors have been elaborated to a much lesser extent than precise methods for optimization with respect to quantitative factors," and because "models of optimal planning do not sufficiently reflect the process of optimization of production relations under socialism. In particular, dynamic models of optimal planning of the national economy are essentially models of quantitative growth rather than models of economic development".[5]

From the above we can draw certain conclusions regarding the relation between political economy of socialism and the use of mathematical methods.

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3. Emphasis added.

4. <u>Ibid.</u>, pp.7-8.

5. <u>Ibid.</u>, p.10.

The debate between the so-called cyberneticians and optimal planners and the political economists is largely a continuation of the Stalin-Yareshenko debate.[6] The tenor of Fedorenko's argument[7] that the descriptive approach (i.e. political economy) be abandoned in favour of the constructive approach (i.e. optimal planning) is similar to that of Yaroshenko's contention that all a socialist economy needs is 'a rational organisation of productive forces' and there is no place for political economy in the socialist formation. Stalin in his polemics against Yaroshenko constructed another artificial wall between planning as a practical pursuit and theoretical political economy by proclaiming that "the rational organisation of productive forces, economic planning etc. are not problems of political economy, but problems of the economic policy of the directing bodies".[8]

Both these approaches border on two extremes. While the Fedorenko-Yaroshenko approach totally rejects any role for political economy and hence disregards the role played by qualitative factors, Stalin's argument undermines the importance of mathematical methods in economic science

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6. J.V. Stalin, Economic Problems of Socialism in the USSR, (Calcutta, 1967) First Indian Edition.

7. See Chapter I.

8. Stalin, n.5, pp.81. He went on to speak of these being "two different provinces which must not be confused".

and the need for a precise knowledge of the quantitative factors in a socialist economy (in any economy for that matter).

A division between quantitative and qualitative analysis is unreal. Novozhilov has correctly pointed out that "Branches of knowledge must be specialized (sub-divided) according to subjects of study rather than according to the methods employed. .... A demarcation between mathematical methods concentrating on optimization with respect to quantitative factors and methods of political economy optimizing with respect to qualitative factors - mainly production relations - is artificial." Novozhilov considers this demarcation artificial as this introduces a gap - "many optimization problems pertaining to qualitative factors cannot be solved without the use of mathematical methods - mathematical statistics, the theory of games, mathematical programming etc. Equally, mathematical methods cannot be properly employed without the use of scientific advances in economic theory. ... Such a gap has negative effect on practical work. After all qualitative factors in the economy cannot be divided from quantitative factors. On the one hand economics knows of no optimization problems that pertain solely to quantitative factors. Here determination of results is based on the comparison and arrangement of qualitatively different use-values".[9]

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9. Novozhilov, n.1, pp.3-5.

It can be said, then, that political economy and mathematical methods or cybernetics etc. are organically and dialectically linked with each other, and for a proper conduct of a socialist economy both have to be developed in unison, as indeed, the development of one facilitates the development of the other. In this sense they both feed each other. However, the relation between the two needs to be qualified, by pointing out, and this is important, that primacy is always to be accorded to political economy, and mathematical economics has to develop in accordance with the guidelines provided by political economy, and has to be subordinated to the latter.

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