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# Systems of Indirect Management in a Planned Economy: Effectiveness Models and Their Applications in Poland

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## Instead of a Formal Introduction

The text of this paper was written during my four months stay with the Cowles Foundation, out of which a considerable portion of time was devoted to other activities. The initial plan of writing a detailed monograph on the applications of optimization models in Poland, in the form of a book, proved to be too ambitious and had to be curtailed. The final chapters became a detailed table of contents rather than an exhaustive text on the subject. There has been no time left to revise the text and hence the consecutive chapters contain some repetitions. I am also fully aware of the nearly complete lack of knowledge of the current Western literature on the subject. This will be partly remedied in the second version which I hope to be able to write more cautiously after receiving some comments. The reason why I dare to present this first unrevised draft in the form of a discussion paper is primarily the lack of any other alternative than its indeterminate postponement. Besides, it might be of some interest to Western scholars to have an account of practical problems connected with the application of optimization models as seen from inside the centrally planned economy and on the basis of a ten year practical experience.

## Acknowledgements

The basic source of success in implementing the first system of indirect management in a centrally planned economy is the collective effort of a team of outstanding persons, both theoreticists and practical planners, who had the courage and the endurance to take up the challenge of introducing new ideas and to implement them.

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Finally, I take this opportunity to express my gratitude to Cowles Foundation for Research in Economics (Yale University) for supporting my research. Special thanks are due to Professor Tjalling C. Koopmans, Professor H. Scarf and Professor M. Montias for the time they were willing to devote for general discussions and comments. I also express my thanks to Miss Linda Lee, Mrs. Laura Harrison and Mrs. Glena Ames for their patience in reading over my manuscript and excellent typing.

# SYSTEMS OF INDIRECT MANAGEMENT IN A PLANNED ECONOMY

(Effectiveness Models and Their Applications in Poland.)

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W. Trzeciakowski

(Preliminary Draft)

Part I: The General Framework of Decision-Making and its Evolution.

1. Decision-Making Systems and Respective Planning and Management Systems.

1.1. Classification Criteria: the Structure of Preferences and the Level of Decision-Making.

The basic assumption of a management system in a socialist[1/] economy is the subordination of the functioning of this economy to the strategy of development as determined by the central plan; the degree of detail of the instruments applied may vary, depending on the achieved stage of economic growth, the degree of diversification of the economy, its reliance upon foreign trade, etc.

If we want to follow the evolution of decision-making systems we may first analyse the impact of both the structure of authority and the management system on resource allocation. Before doing so, however, these two concepts should be further defined as a basis for a classification of resource allocation systems. Basically, the allocation of resources will differ according to two distinct concepts of centralization--decentralization.

- The structure of preferences. In a purely centralized system, the authority or preferences of the centre will always prevail, while in a purely diffused or peripheral system, the preferences of individual decision centres are always reflected by

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1/ By Socialist economy we mean here an economy where the means of production are state-owned.

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the market (market-oriented preferences will therefore be used as a synonym for peripheral or diffused preferences.)

- The management system or the level at which decisions on resource allocation are made. There may be two extreme cases, the first: direct allocation of resources, implying direct orders from the centre, and the second - indirect allocation where decision-making is systematically delegated to lower level units (enterprises, consumers, etc.).

Any combination of a given structure of authority and management system can be defined as a system for resource allocation, even though some specific cases are of purely theoretical interest.

These two categories of classification seem to be helpful in introducing various possible systems of management in a socialist economy.

From the point of view of the criterion of the level of decision-making we can distinguish:

- a strictly centralized system operating with direct orders,
- a system of parametric decision-making in which the method of indirect management is used (the criterion of profit maximization based on the system of shadow prices, exchange rates and interest rates),
- a number of intermediate solutions of multi-level decision-making with the simultaneous use of the methods of direct planning and parametric management, so that both these elements of the system of decision-making may appear in various proportions depending

upon such factors characterizing a given branch of the economy as the degree of differentiation of the product range, the nature of the intended use of the products (for the consumer, as production supplies, for export), the degree of stability or variability of the plan, the length of production runs, the degree of measurability of inputs and outputs, etc.

From the point of view of the criterion of preferences (i.e. "whose preferences are decisive") we can distinguish:

- a system of decision-making implementing the preferences of the central planning authority,
- a system of decision-making implementing the preferences of the market,
- a number of intermediate solutions.

Having in mind these criteria of classification*/, let us concentrate on the analysis of these selected systems of decision-making which are helpful for better understanding of the basic foundations of economic reforms in management.

1.2. System 1: Central Preferences - Direct Allocation of Resources.

A central planning authority determines the allocation of all resources

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*/ A general framework for a comparative systems' analysis of a similar type has been suggested at the Sixth meeting of Senior Economic Advisers, Economic Commission for Europe (April 1968) in the back-ground study: Multi-level Planning and Decision-Making by Margolis, J. and the author.

and the level and structure of intermediate and final demand. The information structure is hierarchical, i.e. it links the central and the executive levels; horizontal links between executive levels are of purely technical character. Downward information flows consist of direct detailed orders concerning output, input coefficients, and production methods. Upward information flows consist of reports supplying the necessary information for central decision-making.

In building up output targets, central planning authorities accept the state of technology and supply of resources as given. The treatment of production methods as an exogenous factor explains the non-parametric role of prices in operative decision-making. The assumption of consistency between output targets and technology greatly simplifies the planning process but leaves no room for satisfying optimal conditions.

In its pure form this system can be considered as the exact opposite to the model of the perfect competitive market. Logically it should imply the direct allocation of labour (choice of occupation) and of consumers' goods (rationing) by the central planning authority[1/]. However, in most applications, provisions are made for individual free choice of occupation and consumption within the overall limits set by the central plan. Earnings from employment have then to be determined so as to direct allocation of labour, and consumer prices are similarly meant to clear the market. Earnings and consumer prices do not, however, influence the structure of production.

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1/ The closest approximation to this model was experienced for a short period of emergency under the name of "War Communism".

The latest version does not correspond strictly to the actual functioning of the centrally planned economies. As any centre is bound to have a limited capacity for processing information into decision, there is a check on centralization of decision-making. Thus certain discretionary authority must be left to the executive levels, incentive schemes with the central preferences must be developed, or alternatively the central level may to some extent adapt its own decisions to the preferences of lower levels. With these reservations, the model can be regarded as an idealized form for resource allocation in a centrally planned economy of the classic type. It explains the general decision-making framework in functional terms and focuses on the consistency of centralized decisions.

In assessing the functioning of the system, the following remarks seem appropriate.

On the one hand, the positive aspects of the system are:

1. the system may contribute to the solution of basic problems facing developing economies, i.e. it allocates a high proportion of GNP to productive investment over a long period, concentrates investment in priority sectors and ensures internal consistency of resource allocation;
2. the system gives the central planning authorities a considerable degree of certainty as to the volume and structure of economic growth, since prices and cost calculations, even allowing for a significant margin of error, do not influence to any substantial extent the development process;

3. the system allows central planning authorities to allocate a relatively high proportion of resources to collective consumption and investment, e.g. education, research in key sectors, and thus to enforce a long-term development strategy:

4. the system gives the high degree of centralization, hence enables central planning authorities to implant the latest technology into the economy and to achieve considerable economies of scale.

On the other hand, the possible drawbacks of the system are:

1. continued growth and diversification of the economy lead to bottlenecks in information flows and central decision-making, thus creating risks of internal inconsistencies in planning and decision-making, and erroneous technological choices on a nation-wide scale;

2. the prevailing sellers' market prevents the productive apparatus from adapting itself to the changing needs of a more affluent society;

3. although the system is well suited to the enforcement of high priority crash programmes[1/], the hierarchical approach used to achieve internal consistency handicaps the "residual" branches especially when the share of these residual branches becomes significant;

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1/ "Any system that at every given point of time fully utilizes the possibilities to the best advantage may yet in the long run be inferior to a system that does so at no point, because the latter's failure to do so may be a condition for the level or speed of long-run performance." J. Schumpeter: Capitalism, Socialism Democracy. New York 1947, p. 83.

4. the high centralization of controls hampers initiative and innovation at lower levels.

The main directions for improvement in the functioning of the system could be envisaged as follows:

- refinement of methods of central planning and management, through an improved processing capacity (use of electronic computers) and the introduction of optimization models above and beyond the traditional consistency checks;
- development of new machinery for indirect planning and management aimed at creating better conditions for initiative and more flexibility in economic decision-making;
- introduction of market elements with the aim of stimulating communication between executive levels.

Some of these points are developed in the next system.

1.3. System 2: Central Preferences - Direct and Indirect Allocation of Resources.

Strict centralization is not possible, neither in plan construction nor in plan implementation. When prices are passive, the behaviour of the executive levels as reflected in their decision, may be guided by non-economic considerations (e.g. preference of technicians, regions or sectors, maximization of premium, authority, or prestige, etc.). The introduction of active scarcity prices and incentives based on centrally fixed rules of behaviour - without limiting the existing sphere of decision-making - broadens the influence of central preferences in spheres previously left outside direct central decision-making. This system may therefore be regarded as a step forward in strengthening the role of central preferences, at the same time giving more room for initiative and flexibility at the level of enterprises.

The basis for rational decision-making at executive levels is the criterion of profit maximization. Profit must be measured in prices containing scarcity rents due tothe existence of alternative uses of raw materials, labour and capital in other branches of the economy, as well as to the existence of constraints in foreign trade and productive capacities. Prices must ensure equilibrium between supply and demand. Marginal foreign trade rates determine actively the scope of profitable foreign trade and perform the price forming function. These rates are an instrument of the analysis of effectiveness of foreign trade and must ensure equilibrium in the balance of trade. All the parameters of the financial system (marginal foreign trade rates, prices, subsidies, duties and taxes) constitute an instrument of indirect management, which ensures that partial profit maximization leads to a consistent and effective overall solution. The main problem lays in building up a well developed system of information suited to the need of determining the values of central parameters and to the necessity of constant verification of these parameters. These conditions cannot be easily satisfied in practice.

### 1.4. System 3: Consumer Preferences Decisive for the Final Demand Structure for Consumer Goods.

The role of the central planning authority is limited to an indirect control of processes in the consumer market within a strictly defined framework. Prices in this sphere are determined not by the central planning authority, but by the functioning of an economic mechanism which is only indirectly regulated and controlled by the central authority.

1.5. Mixed Systems.

In practice we are faced in our economy not with pure systems, but with a mixture of them and a number of intermediate systems.

Between the central level and the executive levels there are intermediate levels, each of which has a defined scope of decision manoeuvering, while the spheres of these decisions are hierarchically related. Between the preferences and criteria of decision-making by the central authority and the criteria at executive levels or the preferences of the consumers, there is a whole range of criteria used by intermediate links exerting a specific influence on the decisions made.

The elements of mixed systems are:

1. central preferences and direct allocation of resources, e.g. in the sphere of long-term and macroeconomic decisions (the rate of growth, the distribution of basic investments, the broad structure of final demand, etc.);
2. central preferences and indirect allocation of resources, e.g. the use of a shodow rate of interest, shadow exchange rates, shadow prices for raw materials, taxes, subsidies, customs and other instruments of indirect government guidance;
3. peripheral preferences and direct planning, e.g. the allocation of investment may be directed centrally, but the criteria used may be based on market principles (maximization of profit measured in market prices);

4. a sphere of decision-making is reserved for peripheral preferences and taken up by enterprises, e.g. allocation of resources for current production, choice of consumers' goods.

These systems are characterized by a multiplicity of decision-making and preference levels. Vertical flows of reports and orders coexist with horizontal links between enterprises. The role of the centre is still decisive (either through direct orders or through the use of indirect measures) but some spheres of decision-making are left to lower levels. Money and prices are, to a large extent, active instruments of resource allocation. Prices are partly determined by the central level, partly fixed by lower intermediary levels of decision-making on the basis of rules imposed by the State, and partly left free to be fixed by the market. The eventual acceptance of a uniform rate of exchange (even only as an accounting tool) plays an important role since it facilitates the comparative measurement of effectiveness between various branches thereby introducing an element of competition into the economy.

The main problem consists in the construction of a framework for the functioning of the market mechanism without impairing the supremacy of the basic preferences of the central planner, e.g. finding a dividing line between types of investments to be determined by central criteria and types of investments to be decided on the basis of market prices. The market mechanism is introduced in selected spheres of economic activity where the central planning authority is ready to accept the individual preferences. This solution relieves the planning apparatus (whether central

or intermediary) of the burdensome task of management in vast spheres of detailed decision-making. At the same time it requires less information flows than management within the framework of a centralized system.

The integration of market-oriented decisions into the general framework of central planning raises, however, more difficult problems than the coexistence of direct and indirect central preferences as seen in the previous system. Here the efficacy of various direct measures are tested and different systems of incentives are applied so as not to allow the market mechanism to act in contradiction to the central plan. The crucial problem is how to reach an overall optimum through partial optimization. A first step is to divide the economy so as to create small subcentres, whose functioning, based on indirect measures of management, would lead to the overall optimum. Next, the distinction between prices determined centrally (at what level of decision-making and by what methods) and prices determined by the market and their mutual interrelationships must be explored by way of consecutive approximations, which - in turn - may tend to create a constantly changing accounting framework. The problem of internal consistency of decision-making occurs not only among different levels, but also among different stages of plan elaboration. How to link planning and decision-making with varying time-horizons, how to ensure that basic decisions on resource allocation made in the framework of long-term strategy are implemented in market-oriented short-run decision-making; these are some of the questions facing the central authority in such mixed systems. The crucial question is how should these mixed solutions satisfy the condition of internal consistency.

## 2. Decision-Making as a Multi-Stage and Multi-Phase Process.

### 2.1. Decision-Making as a Multi-Stage Process.

The techniques of decision-making must be differentiated according to their time-horizon. The more distant the time-span, the greater the scope for introducing changes in production patterns, and consequently the larger the field of manoeuvre in decision-making, the bigger the role of high level decision-making centres.

The vision of the distant future determines decision-making in respect of the immediate future. Ideally, reference to an arbitrarily limited time-span ought to be avoided, but in attempting to identify the whole path of developments leading into the distant future, the planner is faced with the problems of uncertainty. Changes in demographic trends and population structure, changes in productivity resulting from technical progress, future discoveries of raw materials, weather conditions for agricultural crops, future consumer preferences, developments of foreign supply and demand, changes in political and social conditions etc., are all variables either wholly or partly independent of the decisions taken by any planning authority. Planning processes, linking the present to the future, thus represent a series of consecutive decisions taken in conditions of uncertainty, reflecting the sequence of actions and reactions to continually changing conditions. At each consecutive stage of the planning process, the planner will have access to more information about relevant future conditions. A choice that seemed to be optimal on the basis of knowledge available at initial stages of decision-making may reveal itself to be inadequate in the light of new information. The greater the uncertainty in decision-making, the shorter should be the time-span of

binding directives in planning and the larger the scope left for subsequent revisions in longer-term targets. In this context, a distinction ought to be made between the decision-making horizon of a plan and its forecast horizon.

The implied contradiction in decision-making, i.e. between the need to enlarge the field of manoeuvre and the desire to limit uncertainty, makes it necessary in practice to construct separate plans for varying time-horizons which differ in respect of proportions of imperative and forecasting elements, and in respect of aggregation levels.

As a rule, the shorter the time-span, the more imperative the character of the plans; and conversely, the longer the time-horizon, the greater the number of forecasting elements and the more flexible the character of the programme. In a similar way, the shorter the time-span, the more detailed the decisions; and conversely, the longer the duration of the plan, the more aggregated the variables; the many elements of uncertainty to be faced in long-run plans represent admittedly an obstacle to the formulation of detailed directives.

Aggregation and disaggregation give rise to specific difficulties. The use of aggregates rarely leads to solutions fully consistent with those based on disaggregated magnitudes. Hence the need for the application of iterative procedures between plans at different levels of aggregation and disaggregation.

Planning encompasses various decision-making levels. The shorter the plan period, the greater the number of levels participating in the elaboration of the planning decisions. In practice, it is indispensable

to apply a process of approximating the final solution in consecutive steps and phases. The results of the interplay between central and sectoral planning may converge very slowly; in consecutive phases new constraints are discovered, targets are reformulated and additional preferences are expressed. This procedure does not lend itself to simultaneous solution by a mathematical comprehensive model, and at present there seems to be no other satisfactory practical solution.

Individual decisions can be classified as referring to long-, medium-, short-term and management time-span, using the same criteria as for plans, but when grouping decisions within a plan of a specific time-horizon, it should be kept in mind that the individual decisions involved may refer to different time-spans not fully corresponding to the time-horizons of the plan in question. The gestation period of investment in different branches, for instance, may vary from a few days to ten years, or more; within the framework of one and the same medium-term plan both investment and current criteria of analysis will therefore have to be applied. Whatever the formal time-span of planning, any overall plan must in some sense be open-ended.

When looking at all the plans with varying time-horizons as a multi-stage decision-making process, the general and highly simplified scheme[1/] may serve as an illustration (Chart 1).

As illustrated in Chart 1, each decision referring to the longer time-span provides a basis for a decision concerning a shorter time-horizon, but at the same time the former is directly affected by changes in the latter. This means that planning takes place as a process of consecutive iterations in time.

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1/ Compare R. E. Kitchell: Program Budgeting. Harvard University Press, 1965.

There are different types of mutual interrelationships of plans with varying time-horizons. At the one extreme, consecutive five-year plans and yearly plans are supposedto conform to binding long-term directives. Plans referring to longer time-spans have then to include all necessary specifications for building up the shorter-term plans, a nd, at the same time, their context should be relatively independent of short-term changes in the economy. The question remains open, however, whether these two requirements are compatible (Chart 2).

At the other extreme, longer-term programmes are looked upon as subsidiary instruments for analysis and forecast, and planning consists in constant adaptation of decisions to changing conditions. The long- and medium-term programmes are built up every year to throw light on possible future developments and to show what seems to be feasible and desirable (Chart 3).

It is obvious that constant revisions of plans are connected with very high costs, but these costs should be assessed against the benefits of actual decisions being taken on the basis of more accurate information. Since uncertainty and possible losses due to erroneous information increase with time, insistence in adhering to a long-term plan may involve important losses.

Thus neither of the two systems or any intermediary form can provide complete safeguard against the costs resulting from uncertainty. With the flexible planning system, consumer demand will tend to be satisfied on the basis of a sometimes inadequately adapted structure of productive capacity, excess facilities or shortages appearing here and there, with the rigid

planning system, the producers will be able fully to utilize available capacity, but the structure of output will not necessarily correspond to actual demand, redundant stocks or shortages in the consumer market becoming frequent features. This is especially important in foreign trade.

The general conclusion would seem to be that the very nature of the decision-making process requires continuous reference to interrelated plans with a range of time-horizons. Long-term planning without due regard to the exigencies of short-term planning or implementation becomes an academic exercise of poor operational value; whereas annual planning that ignores the coordinated needs of a development plan tends to disperse national effort and hold back progress towards rational investment objectives.

Actually applied planning procedures constitute a compromise containing certain predominant features characteristic for the one or the other extreme system. The main types of plans classified according to time-horizons are the following:

- perspective programmes covering 10-20 years representing approximately the maximum period for which projections may meaningfully be established by policy makers;
- medium-term plans covering five years, corresponding to the gestation period for major investments;
- short-term plans;
- operative (decision-making in management).

The long-term perspective programme[1/] deals with large aggregates.

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1/ M. Kalecki: 1. An Outline of a Theory of Growth of a Socialist Economy. Warszawa 1963. 2. Zarys teorii wzrostu gospodarki socjalistycznej. Warszawa 1968. K.Porwit: "Planning in Poland." Warszawa 1967.

Selection of efficient investment patterns is effectuated on the basis of an analysis of technical progress in aggregated domestic sectors and expected developments abroad. General trends in foreign demand - but not in specific markets and prices - are explored. Aggregate capital-output ratios are investigated. At this stage the main task is to formulate a general strategy of development.

Medium-term planning is mainly concerned with the choice of investments, and commodity structure of production, exports and imports. Regional allocation of foreign trade (if any) is analysed in aggregate form. Domestic costs including the rate of interest on investment are taken into consideration. Since the distribution of investment to optimize the production structure is a major issue, productive capacities cannot be regarded as given.

Short-term planning deals with the time-span of one year. The question to be answered is what and how much to produce, what and how much to import, where to sell and where to buy. Productive capacities are regarded as given (constant), current costs have to be taken into consideration. Investment outlays do not enter the analysis, however,

In the shortest time-span, i.e. in current management, the decision-maker commands certain stocks of commodities and has to decide where to sell them. Analytical findings in respect to actual demand, prices and payment conditions will determine the optimal solution of his problem. Stocks being already at hand, alternative structures of production and cost are not relevant here; the rational choice consists in selling them

on most favourable terms.

The relative importance of these plans with varying time-horizons was different in the consecutive stages of development. Long- and medium-term planning were rather practically neglected in the early periods of our planned economy. On the contrary - the directives of the yearly plans were decisive. Planning had nothing to do with forecasting, it was an obligatory directive, and instrument of current management and of control of the functioning of the economy. There was no place and time for a comparative analysis of variants of possible strategic choices, planning meant the elaboration and coordination of detailed short-term directives. Gradually, however, it has come to be considered that the predominance of the annual plan weakens the contribution that planning can make to purposeful economic development. Hence the present trend is on the one hand towards strengthening long-term programming and related medium-term planning and on the other hand towards enlarging the sphere of indirect methods of management at the expense of short-term planning. This leads to the development of new techniques of projections, taking into account uncertainty, increases the role of forecasts and evaluation of variants and strengthens the importance of effectiveness analysis. This general trend is a characteristic feature of the evolution of the whole system of planning, but is especially relevant in the domain of foreign trade planning.

2.2. Decison-Making as a Multi-Phase Process.

The relations between macro and microplanning are complex. However,

from the point of view of the central planner, three broad successive phases can be distinguished,[1/] and are illustrated in Chart 4.

In the first phase, planners at the central level work out preliminary directives forming a comprehensive draft of the general economic plan. The main function of these directives is to influence projections on the sectoral and executive levels. The better the first guess of the rate of growth in the preliminary directives -- the smaller the number of necessary iterations (cycles of projections) subsequently required to obtain a feasible programme. As the formulation of preliminary directives relies on information received from lower levels, and as plans are constantly verified and adapted to changing conditions, planning is a continuous process. Changes of global proportions affect, by the sectoral adaptations which they entail, the plans drawn up at enterprise level; and, in the opposite direction, changes in technological processes at the enterprise level require, again via the sectoral plans, changes in global proportions.

In the second planning phase, draft plans are elaborated by sectoral boards, foreign trade and productive enterprises. They are supposed to meet requirements of consistency.

The central planning authority seeks to preserve centrally determined proportions, but has to deal with aggregates that can be disaggregated.

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1/ Cf. J. Pajestka: System informacji planistycznej. "Ekonomista" No. 2, 1964.

Consequently, it is only when the detailed proposals put up by the lower planning levels have reached the centre that the macroeconomic proportions can be checked and, if the two sets of indicators match, that the macro-proportions be confirmed in the third planning phase as feasible aggregates and take the form of binding directives. To attain consistency it is normally necessary to repeat the procedure several times, although the subsequent cycles of approximation may proceed in various informal consultations, conferences of planners from all levels, etc.

This complex and iterative procedure requires time, it encompasses thousands of planners, experts and workers' councils, and it has to provide solutions to difficult problems of consistency-keeping. But time is limited, since planning is concerned not only with establishing the best programme, but also with current direct economic management; consequently the iterative procedure has to be interrupted before all inconsistencies have been removed, their resolution being postponed to the stage of plan implementation.

No form of planning yet devised is capable of replacing the participation of thousands of planners at various levels in a process of plan building during which all the limitations on, and complex interconnections, priorities and changing conditions of, the economy are taken up in what amounts to a system of virtually constant consultation. All these factors could not be assimilated into planning by means of direct application of an abstract model that replaces planners at the executive level. This does not mean, however, that mathematical tools are of little use; on the contrary, the application of new techniques of data-processing throughout

the economic apparatus of the country, as well as the use of certain macromodels in conjunction with traditional methods of analysis, facilitates the realization of the main task of linking central economic calculations with decentralized projections and decision-making.

## 3. The Selection and Sequence of Spheres of Implementation of Efficiency Systems.

### 3.1. The Mathematical Economist's Approach.

The mathematical economist who wants to influence practically the functioning of the decision-making processes is faced with basic limitations which determine his general approach.

First, there is the problem of the general attitude of the Central Planning Authority towards the introduction of efficiency systems. There seems to be no doubts anymore, that with the growing complexity and diversification of the Socialist economies, there is a general understanding of the ever growing role of efficiency requirements in decision-making. Hence there are no antagonistic contradictions between efficiency and central planning. However, some reservations should be made here. It seems necessary to make a distinction between the general preferences of the central planning authority expressing the overall economic interests of the country and preferences of individual decision-makers, representing the partial interests of specific branches, regions or enterprises. There are obviously situations, where the general overall efficiency requirements are in conflict with vested interests of some branch - or regional policy-makers. The process of transformation of a

non-efficiency system of direct management via administrative orders into an efficiency system of mixed (direct and indirect) management creates several basic tensions and conflicts. These conflicts can be overcome only when overall optimization criteria assume a decisive importance and priority over partial preferences. In the political set-up of a centrally planned economy, this requires a strong power of the central authority conscious of its overall aims. Hence any successful implementation of an efficiency system requires a strong political support of the highest policy-making body which is convinced of the necessity of economic reforms, and which represents the general and not partial preferences.

Now we come to the second basic problem: what can economic systems theory offer to the central planner in exchange for his strong support for the model-builder. First of all, the policy-maker expects from the model-builder that the proposed changes will neither damage nor endanger the functioning of the overall system of decision-making. If long-term investment decisions are to be taken up within a framework of a new decision-making system -- uncertainty and increasing returns to scale must be built into the methodology of the selection of variants. If iterative procedures are suggested, the dangers of non-convergence or slow-convergence of the system must be assessed as no deterioration of existing solutions is tolerable. The mathematical model-builder who is invited to cooperate with the policy-maker and the administrator cannot neglect the existing decision-making procedures and impose his own solutions derived from a theoretically correct but abstract model, without due regard to the multi-stage, multi-phase and multi-level character of actually functioning planning -- management and information systems. Hence a stage-wise and evolutionary

approach to decision-making systems seems to be fully justified. A further condition - often neglected in practice - is the preservation of the internal logic of the overall system of decision-making in a planned economy. One is often tempted to transplant some solutions, worked out on the basis of model-assumptions very remote from the reality. The existence of a competitive market, the motivations of a private investor, non-existence of planning authorities, or the non-directive (indicative) role of central planning - are examples of explicit or implicit assumptions having nothing to do with socialist reality. All these examples illustrate the dangers of accepting ready-made systems not adapted to the existing conditions and therefore exposed to the danger of "rejection of transplants." Hence the need for original solutions derived from models consistent with the assumptions of a planned economy and with the needs of a normative approach aimed at the improvement of the existing decision-making processes.

### 3.2. The Separate Treatment of the Short-Run System and its Basic Tasks.

In the economists' - rather common - opinion the weakest link in the decision-making multi-stage chain is efficiency in short-run decision-making. One may argue - at least in theory - that short-run efficiency cannot be separated from efficiency in the long-run. However, this would lead us nowhere because of the complexity of the multi-level and multi-period problem of decision-making. As has been already shown, the very complex economic decision-making processes have been divided, in practice, into separate plans with varying time-horizons. Though certainly this is not the best theoretical solution, there does not seem to exist another practical approach to the multi-stage problem of decision-making.

As has been pointed out, the longer the time-horizon, the greater the uncertainty. Hence, models adapted to the needs of long- and medium-term decision-making should be dynamic (i.e. consider the behavior of the economy over time) and should take into consideration uncertainty conditions. As long- and medium-term decisions are mainly concerned with the choice of basic investments - such models should take into account the existence of economies of scale.

The question looks differently, however, in the short-run. It can be reasonably assumed that the problems of timing, uncertainty and economies of scale have been taken into consideration in the course of planning processes aimed at determining plan targets. Hence, short-run models for decision-making in management can disregard timing, uncertainty and economies of scale, focusing their attention on these features which are characteristic for the short-run.

The real problems that count in the short-run are the magnitude of decisions, their implementation and the ever-growing importance of efficiency requirements. Therefore, what is needed is a rational system of short-run management that could effectively guide decentralized decision-making, preserving the overall preferences of the central planner and, at the same time, not hampering the initiative of executive levels of decision-making. It remains to be seen whether these tasks are mutually compatible.

### 3.3. Factors Influencing the Selection of Spheres of Decision-Making Systems.

As has been already pointed out in Chapter 1, the short-run mixed

management system consists of two types of decision-making: centralized direct orders and indirect management based on profit maximization criterion and using parametric prices.

The selection of spheres of decision-making reserved for direct management and indirect management, respectively, is determined by the following factors:

- the existing capacity to process information into decisions at various levels of the economic structure in relation to the magnitude of the problem, the degree of detail, the importance of information flows, the frequency of data modifications, the fluctuations in parameters, etc.;
- practical considerations connected with the preferences of the central authority. These include determination of rates of growth, sectoral distribution of basic investment, structure of final output, overall volume, basic structure and main directions of foreign trade, and distribution of national income. Decision-making concerning the details of the general development pattern in short-term plans, i.e. the structure and output of any given enterprise, its supply sources and outlets, etc., may require more flexibility in decision-making and thus may be left to executive levels. Their decisions will be generally influenced by the centre's macroeconomic decisions, as expressed in general directives;
- the organization of the economy. The division of the economy into separate units determines the method of management, i.e. the use

> of quantitative orders or of shadow prices. It follows that the central planning authority can adapt the management method to the existing organizational framework or it may change the structure of the organization to extend the use of direct or indirect methods of management. In practice, there is need for a flexible approach - since neither total centralization of decision-making nor exclusive use of indirect methods can lead to an optimal solution. What compromise should be adopted is the heart of rationalizing multi-level decision-making. 1/

The first area of economic activity in which it is possible to determine the prices objectively is the widely interpreted sphere of production and trade related to foreign trade. In this sphere competition from foreign markets is felt and there exist real and measurable exports and

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1/ Two approaches may theoretically be applied to the basic problem of multi-level planning in a large economy:

- dividing the overall problem into partial subproblems, which can then be dealt with separately;
- using the indirect (shadow prices) approach instead of the direct approach.

But the concept of duality (i.e. the equivalence of the overall direct optimization with partial optima based on shadow pricing) is fully applicable only in an "atomistic" economy; even so, there are limitations to using prices as instruments of optimal allocation (externalities, indivisibilities, linearities of production functions, etc.).

and imports alternatives. Because of the possibility of comparisons of effects in various branches of production there is here a lot of room for manoeuvre in selecting variants of the structure of product range, of the geographical distribution of exports and of substitution in the consumption of materials.

Another broad area in which there exists an objectively determinable system of equilibrium prices is the sphere of consumption, wherever the consumer preferences are not in conflict with the general social preferences.

A further area in which it is possible to introduce an effectiveness incentive-active financial system are those branches in which the outlays are measurable by cost accounting, in which the existing limitations on the productive capacity lend themselves to accounting analysis and in which the essential limitations and relations can be realistically included in operations research analysis for the whole branch concerned. The limiting factors here are: the extent of calculations, the degree of differentiation and variability of the production, the extent of bonds with the rest of the economy, and the stability of the parameters of the system.

It can be seen that there exist very extensive possibilities of expanding the scope of operation of an effectiveness incentive-active financial system in our economy providing that rational principles are observed in determining prices, exchange rates, surcharges and charges consistent with the logic of the decision-making system adopted in a specific model of management.

The introduction of an effectiveness incentive-active financial

system must be additionally related to the satisfying of the basic condition concerning the price fixing mechanism. Similarly, as a student cannot give marks to himself, so under the conditions of transition to an effectiveness incentive-active financial system safeguards must be provided for a consistent division of interests of the authorities determining prices and the units to which incentives are applied for the achievement of the target. This postulate leaves much to be desired in the practice of our system of management in the field of determining prices as well as in the field of determining direct targets; the authority which determines the targets (or the prices) approves, in practice, rather than determines the proposals for the interested parties and, at the same time, is often judged itself on the basis of the realization of the targets (and so is itself interested in not stretching them too far).

The postulate of determining prices in a way independent of the involved links of the production apparatus is also essential in the sphere of production of consumer goods. The monopolistic structure of production for the consumer market makes possible the formation of the monopoly rent under the conditions of the existence of incentive relations between the production of consumer goods and the results. It is possible here to manipulate the volume of production and to limit supply. Thus the introduction of an effectiveness incentive-active financial system must be accompanied - in the case of existence of such a monopoly - either by the strengthening of price control by the government, or by the formation of import intervention fund which would eliminate the monopolistic position of the producers inclined to take advantage of the monopoly rent.

3.4. The Logic of the Historical Evolution of Spheres of Implementation of Efficiency Systems.

The consecutive stages of this evolution will be dealt with in more detail in Part III. Here we will draw the attention to the sequence of implementing the various short-run efficiency systems into practice. The first attempts to introduce some indicators of efficiency took place in foreign trade in the late fifties. One discovered the absurdity of some direct orders to export given commodities, when it became evident that the foreign currency value of raw materials surpasses the foreign currency value of the final product composed of these raw materials. At the same time the export of this final product was rentable in terms of domestic currency, due to the distorted internal pricing of raw materials. As the separation of internal prices from external influences was looked upon as an essential feature of the centralistic system of planning and management, it became necessary to introduce a separate system of efficiency indicators, that could check the correctness of specific export plan-targets. These indicators, however, as all partial indicators, were mutually inconsistent, and hence a demand from the part of the Central Planner for an overall system of short-term optimization in the field of foreign trade (1960). The required system has been derived strictly from a mathematical model, described in Part II. On the basis of this model a complex system of calculative prices of basic materials was constructed, and starting from 1962 catalogues of calculative prices and price indexes were worked out on a yearly basis (with some quarterly changes when necessary). To make it possible -- a special system of statistical and plannistic analysis had to be introduced to determine the values of central parameters (marginal rates of substitution between the Polish Zloty and foreign currencies).

Later on (1964), the attention of the Central Planner was drawn to the necessity of determining criteria for the selection of fast recuperating investments connected with foreign trade. Hence, a respective Mathematical Model of Fast Recuperating Investments has been constructed (described below in Part II, Chapter 3), and the criteria of choice of variants applied into practice. However, the efficiency criteria applied to direct planning decisions only could not meet the rising demand for efficiency. The active role of Central Planning was, in fact, limited to priority sectors, as the "residual" sectors were dealt with in aggregates and with no consideration for overall efficiency calculus. Hence, the necessity to connect efficiency calculus in foreign trade with an incentive system, so as to be able to influence indirectly/also the behavior of these residual sectors. Once this has been introduced (1966), the Central Planner became acquainted with the new categories of an indirect system of management and with the numerical values of central parameters, the magnitude of profits and premiums in various branches and specific enterprises. The next exploratory step was the replacement of the calculative approach (calculative prices) by a financial system that could actively induce the behavior of firms in accordance with the principles of rational allocation of resources. This has been implemented in practice in 1967 in the form of an experiment ("POLFA" - see Part III, Chapter 12). Following the excellent results achieved in both experiments (the incentive system and the financial experiment) a new step forward has been undertaken: the general reform of prices for producers (introduced on January 1, 1971) This created the possibility of enlarging the analysis of efficiency to encompass the whole economy. Hence the next step which is being elaborated: how to construct a system of short-run efficiency that would be fitted into the overall financial system. Several theoretical proposals

have been worked out that show the way how to enlarge the spheres of implementation of efficiency systems to various sectors. However, the problem of an overall implementation has not yet been solved neither theoretically, nor practically.

## II. Models.

### 4. The Stage of Partial Analysis of Effectiveness in Foreign Trade.

#### 4.1. The Need for Effectiveness Analysis.

As already mentioned, historically, the need for efficiency analysis occured first in foreign trade.

In a centrally planned economy of the classical type, there is no market mechanism, the rates of exchange of foreign currency are established more for book-keeping than for strictly economic purposes, and the domestic structure of prices and costs is quite separate from respective foreign price relations. Domestic prices differ substantially from costs of production on account of "accumulation margins" (either positive or negative); and further discrepancies result from domestic pricing of imported raw materials.

Problems of effectiveness analysis occur when there are possibilities of choice. In short-run foreign trade analyses such possibilities occur in planning the assortment of production and in selecting trading partners; and as a rule there is the ancillary problem of determining which amount of limited investment resources should be allocated to fast recouperating investments. More specifically, the following decisions have to be taken:

- which export commodity to choose?
- whether to produce domestically or to import?
- which markets to export to or to import from?

- which amount of limited investment funds to allocate to the quick promotion of productive capacities for export or import substitutions?

In the development of foreign trade effectiveness analysis as rational means of providing answers to these questions, two main consecutive stages can be distinguished: first, the construction of separate coefficients of export effectiveness, based on various partial criteria; and, second, the construction of comprehensive macromodels, encompassing exports as well as imports, and derived from the global plan model.

## 4.2. Partial Effectiveness Criteria [1/]

In all the coefficients described below, the distorting effects of the official exchange rate are circumvented by comparing directly the world market prices with domestic costs.

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[1/] The first attempts to formulate partial effectiveness criteria in Poland were elaborated by:

- J. Pajestka: "Zagadnienia Rachunku Rentownosci Handlu Zagranicznego" (Problems of Rentability of Foreign Trade) in Ekonomista, No. 5, 1957.
- A. Rolow: "Podstawy Rachunku Efektywnosci W Handlu Zagranicznym" (Foundations of Effectiveness Analysis in Foreign Trade) in Handel Zagraniczny, No. 12, 1956.
- S. Polaczek: "Zastosowanie Kursow Wynikowych W Badaniu Efektywnosci Eksportu Poszczegolnych Towarow" (The Application of Effectiveness Indicators in Effectiveness Analysis of Individual Commodities) in Handel Zagraniczny, No. 11 and 12, 1958.

Financial Indicator. The most simple coefficient, intended to provide a general notion of effectiveness, was the so-called "financial indicator F", which compared foreign and domestic prices:

$$F = \frac{P}{D} ,$$

where: P - domestic price,

D - world price in foreign currency (f.o.b.).

The only merit of the indicator was its simplicity and aggregativeness - in the sense that it could be calculated for individual commodities as well as for global transactions. While it provided information about the purely financial profitability of transactions (exports as well as imports), it was plainly unsatisfactory as a measure of overall economic effectiveness; for it concealed those price distortions caused by varying accumulation margins as well as those due to the arbitrary domestic pricing of imported raw materials.

Last-phase Labour Cost Indicator. In the search for a correct measure of effectiveness in terms of labour costs and hence free of all the distortions arising from the domestic pricing of materials, a "last Phase Effectiveness Coefficient L" has been devised.

$$L = \frac{P - M_d - A}{D - M_f} = \frac{C_l}{D_l}$$

where:

P - domestic price;

$M_d$ - cost (measured in domestic prices) of all raw materials, semi-products and other material inputs used for the production of the final product;

A - profit at last stage of processing (accumulation);

D - world price in foreign currency (f.o.b.);

$M_f$ - cost in foreign currency (measured in world prices) of the same materials, calculated in $M_d$;

$C_l$ - last phase processing cost;

$D_l$ - net gain of foreign currency, earned at the last phase processing costs.

By focusing attention on the net gain in terms of foreign currency, this coefficient obviates the danger of choosing an export with a negative foreign currency effectiveness (i.e. with a currency loss).

In the numerator, the domestic processing costs of the last processing phase are shown (i.e. from the f.o.b. domestic price, profits as well as all costs of materials used in production are eliminated); and in the denominator, the last stage foreign currency net gain appears (i.e. all material inputs evaluated in world prices and secondary expenses borne in foreign currency are subtracted from the f.o.b. world price).

This indicator is free from distortions caused by inadequate domestic pricing of materials, and it therefore provides a correct measure of the profitability of the last phase of the productive process. But the usefulness of this, as of the other indicators described above, is limited, inasmuch as it is commodities, and not phase of production, which enter into trade. Moreover, this index in its quotient form neglects the existence of limitations of various kinds (foreign supply and foreign demand,

productive capacity, raw material reserves).

Coefficients of Material Intensity. The labour effectiveness quotient indicators described above neglect the existence of various contraints, notably shortages of raw materials and limitations of productive capacity. Yet, in all developing economies these limitations are decisive and therefore cannot be disregarded. If only a limited amount of raw materials is available for export, then a better labour effectiveness indicator for the first than for the further, more refined, processing stages does not mean that the former is more profitable. Indeed, the opposite preference prevails--namely, to earn as much foreign exchange as possible from the limited raw materials available, and plainly the more highly processed, final products sell for much higher proceeds than the less processed semi-products. In that case the order of priority may differ from that indicated by labour effectiveness coefficients. Hence, when raw materials are in short supply coefficients of material intensity are constructed.

These coefficients of material and import intensity are based on the following formulae:

$$M = \frac{M_f}{D} \quad , \quad M' = \frac{M_e}{D} \quad , \quad M'' = \frac{M_i}{D} \quad ,$$

where:

$M_f$ - the value of all material inputs at world prices;

$M_e$ - the value of exportable and imported material inputs at world prices;

$M_i$ - the value of imported material inputs at world prices.

These diverse variants of "material intensity" and "import intensity" coefficients are used for comparisons of export commodities and favour the export of commodities with lower material--or import intensity coefficients.

4.3. Shortcomings of Partial Methods of Effectiveness Analysis.

The introduction of the various coefficients of the labour or material effectiveness of exports described above constituted an important first step towards introducing optimization criteria in foreign trade planning methods, which had previously been solely concerned with obtaining consistency. After some experience of their applicability had been gained, however, it became evident that the theoretical foundations of these coefficients were far from satisfactory and that a new more comprehensive approach to the problems of foreign trade optimization was needed.

In addition to the specific shortcomings already noted, the earlier techniques of effectiveness analysis had more general methodological weaknesses. In the first place, the system of diverse coefficients provided partial, but not general, solutions by yielding different--and sometimes contradictory--orders of priority, depending on which indicator was used. Since, in short, all these coefficients were mutually inconsistent, no general rules of decision-making, based on them, could be formulated.

One of the gravest weaknesses of the early effectiveness analysis

was the failure to include imports (except so-called "anti-import" production). Thus, an important segment of foreign trade turnover had no influence on foreign trade profitability calculations, despite the evident importance of differences in the prices for imported commodities on different markets.

Moreover, all the coefficients described earlier were calculated in world prices, disregarding the differences in the general price levels on different clearing markets and the different commodity structures established in bilateral clearing agreements. Plainly, in conditions of bilateral trade in inconvertible currencies, foreign exchange transactions cannot be accounted at their face value. A number of attempts were made to deal with this problem by building separate sets of coefficients for basic payment groups. This procedure, however, considerably reduced the possibilities of comparing indicators for various markets. Besides, there remained the question of solving "mixed" cases, in which raw material inputs were imported from one type of market and final goods were exported to another.

For the range of application of effectiveness criteria in planning and operative decision-making to be increased, they must take into consideration: first, all the relevant conditions obtaining in foreign trade (i.e. not only foreign prices, but also foreign supply and demand); second, all the relevant conditions obtaining in production (i.e. not only domestic costs, but also productive capacities and raw material resources); and third, the treaty arrangements in foreign trade (convertible or inconvertible currency, multilaterial or bilaterial terms, etc.). The use

of mathematical model analysis is helpful in meeting such complex requirements: it allows the construction of optimization criteria derived directly from a general model. These criteria contain central parameters, obtained from the overall analysis, which also reflect the preferences of the central planner. Once the criteria have been derived by mathematical methods and the central parameters have been calculated at the central level, the practical application of the effectiveness criteria at the executive level can rely on traditional methods. For the system of effectiveness analysis to be workable, however (i.e. it has to be broadly used by planners and managers), it must be simple. The principle of profit maximization--measured in planners' opportunity costs or shadow prices--would appear to satisfy this requirement, for it renders effectiveness calculations appropriate for practical decision-making at the executive level, while preserving the preferences of the central planner. The system of effectiveness analysis must also be comprehensive, i.e. it must encompass the analysis not only of exports, but also of imports. Finally, effectiveness analysis must meet the requirements of flexibility in decision-making, which is particularly important in the conduct of foreign trade.

The system of effectiveness analysis is, therefore, primarily intended to determine, on the one hand, the operative criteria of effectiveness necessary for short-term planning at the central level, and, on the other, optimization criteria for the executive level.

A model for the optimization of foreign trade [1], and a general model of short-term overall economic planning [2], has been developed in Poland; the main central parameters (marginal rates and shadow prices of basic raw materials) have been computed; and the principle of profit maximization in terms of these planners' shadow prices has been introduced as a guiding directive for executive levels in the plan building process.

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[1] Cf. W. Trzeciakowski: 1. Model optymalizacji biezacej polityki kierunkowej w handlu zagranicznym. "Gospodarka Planowa," Nos. 8-9, 1960. 2. The Model of Optimization of Foreign Trade in a Centrally Planned Economy. "Proceedings of the Regional Science Association," The Hague 1961 (edited by W. Isard), New York 1962.

[2] J. Mycielski, K. Rey, W. Trzeciakowski: Decomposition and Optimization of Short-run Planning in a Planned Economy in "Structural Interdependences in Economic Development" (edited by T. Barna), London 1963.

## 5. The Model of Short-Run Optimization of Geographical Allocation of Foreign Trade.

### 5.1. The Initial Set-Up.

If foreign trade consisted exclusively of multilateral trade agreements with free convertibility and full transferability of balance of payments' surpluses from one trading partner to another, then the general rule for optimizing the directional foreign trade policy would be quite trivial: "buy on the cheapest markets, sell on the markets with highest prices," the geographical comparison of prices being effectuated by the use of obligatory exchange rates. The basic assumption, however, is far from reality.

If a "world market" or "free market" existed, on which all "our" commodities could be sold and bought, and if there were no quantitative restrictions on trade with separate markets, then an objective basis for comparing prices expressed in foreign currency would be available. Relations of foreign prices on various markets, established on this basis would constitute the criterion of choice of the "best" market. However, price comparability is limited not only by the lack of a market on which everything could be evaluated, and by qualitative differences of commodities which make them incomparable, or difficult to compare, but basically by serious limitations of the commodity structure and quantitative restrictions on exports and imports.

If foreign trade consisted exclusively of bilateral trade agreements with full non-convertibility and non-transferability and with

no interflows of inputs among markets and no possibilities for alternative allocations of individual commodities to various markets, then there would be no need for directional comparisons and hence no reasons to change the centralistic system of decision-making, determining separately the commodity structure of foreign trade agreements with individual countries. However, again the assumptions do not hold. Reality dislikes pure models, and is much more complex.

Within the general framework of Foreign Trade State Monopoly decision-making in foreign trade has been initially highly centralized. Plans with different geo-political regions were constructed separately. Trade with Socialist and developing countries was based on bilateral agreements with non-convertible currencies. Trade with Western developed countries was based either on multilateral or bilateral trade agreements, however, the notion of multilaterality and convertibility was often impeded by special treaty restrictions, constraining the magnitude of the admissible balance of payment surplus. Eventual imbalances were bilaterally negotiated within the framework of short- medium- or long-term credits, with no transferability to third markets. At the same time with the constraints on free convertibility of currencies, structural commodity restrictions (of a discriminatory or non-discriminatory but lasting character) determined partly the commodity pattern of export and import and limited the possibilities of changing the geographical allocation of trade. This resulted in a different commodity structure of trade with Socialist , Western developed and developing countries. Due to the limitations of

of currency transferability and to the constraints on trade, there occured important differences in price levels on different markets: price levels obtained for exports varied from price levels required for imports, prices for similar commodities were incomparable in their nominal valuation, as official rates of exchange were void of any economic meaning in conditions of bilateral trading with non-convertible currencies. Hence the question of how in these conditions exports and imports should be rationally allocated becomes a complex and non-trivial task.

The initially highly controlled model of decision-making in foreign trade was well suited to the requirements of the first stage of extensive development in the period 1950-1956. In that period the average yearly rate of growth of the national income produced was higher than that of exports. Macro-concepts of the central planner imposed on the whole economy through the system of planning directives were the driving force of the development. The strategy of autarkic growth and complex industrialization postulated an isolation of the internal economic system from external direct influences. The share of foreign trade in the domestic output was not only negligible, but also its structure was little diversified. [1/] This facilitated a centralized model of decision-making. What really mattered was import. Export was looked upon as a source of foreign currency to cover the indispensible import needs. The foreign trade plan listed in kind the specific amounts of goods to be exported and imported. This type of planning ensured not only a vigorous discipline in maintaining the required volume and structure of foreign trade, but also facilitated the maintenance of internal consistency of

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[1/] E.g. in 1955 export earnings for eleven commodites amounted to 80% of the total value of exports.

commodity balances fixed by the plan. Efficiency considerations were not treated as important. Hence in these initial development stages, foreign trade was looked upon as a residual, not as a factor creating national income. Another important role of foreign trade was its function of shock-absorber, consisting in counter-acting the unforeseen deviations from the plan targets occuring in the course of plan implementation. The accepted system of organization separated the responsibility of foreign trade activities from production for export. The detailed foreign trade plan was binding as well for foreign trade enterprises as for producers' enterprises. However, industrial enterprises were not interested in the level of foreign trade prices received and paid. There was no connection between foreign trade and domestic prices. The obligatory fixed rates of exchange had a completely passive and formal computational character with no influence on the level of domestic prices and hence no influence on internal decision-making. The basic task of the foreign trade apparatus was the implementation of import targets (reflecting the central developmental preferences) through disposable exports, while securing the balance of payment equilibrium. Hence, in general, the importance of efficiency considerations was negligible, but the central control of the geographical structure of exports and imports was nearly perfect.

However, the rising share of foreign trade and its growing diversification lead to a qualitative change of its role in the economy. The

growing complexity of the economy and specifically of foreign trade resulted in a change of the character of planning directives on various decision-making levels. Contrary to the previous methodology--the central planner limited drastically the number of items determined in kind and enlarged the share of planning targets expressed only in value terms. Targets expessed in value terms were general in nature and left space for the optimization of the commodity structure of foreign trade. The rising diversification of foreign trade commodity structure enlarged the sphere of allocation possibilities. But the knowlege of specific constraints characterizing individual commodities on particular markets is the exclusive domain of the foreign trade enterprise, and not of the central planner. All this leads to a gradual decentralization of decision-making in the framework of the planning system, creating much larger possibilities of adapting the geographical directions of foreign trade to the changing needs without impairing--at least in priciple--the leading role of the central planner. This change in methodology of foreign trade planning created of course a demand of effectiveness criteria adapted to the needs of rational decision-making in planning at executive levels. What was now expected from the effectiveness model-builder was not only the derivation of analytical criteria of choice, but also the construction of an indirect mechanism for the guidance of decentralized choices in accordance with over-all preferences.

Here comes the most difficult and complex question: how to ensure the mutual consistency between decision-making at various management

levels so that an over-all optimum could be reached through partial optimization processes. On the one hand, there must be a set of consistent optimization rules derived from an identical model common to all decision-making levels. On the other hand, optimization prescriptions must be suited to the existing decision-making pattern of each specific administrative level, determined by its tasks, sphere of maneuvre and information system. The construction of an over-all geographical foreign trade plan relies on more aggregated information and results in more general directives than the elaboration of a particular bilateral trade agreement. The latter may partly rely on more detailed information and directives (items specified in kind, determining the volume and value of trade) and partly on aggregated "non-specified" commodity groups fixed approximately in value terms. In turn, these "non-specified" commodity groups can be translated into specific export or import decisions by individual enterprises, as only they are disposing of very detailed information necessary to negotiate specific commodities (prices of specific commodities on particular markets, constraints on foreign supply and foreign demand on each market, quality requirements, delivery terms).

Experience shows that there is no possibility of constructing an over-all numerical model, that would be able to replace the whole chain of multi-level decision-making processes, both because of the computer processing capacity constraint, and because of the information collection constraint (the last being especially important in foreign trade, where information is being collected in the course of negotiations). Hence,

the following approach has been accepted:

- first, the formulation of a general algebraic (non-numerical) model of optimization of directional allocation of foreign trade; the analysis of the properties of the optimal solution of that model leads to the determination of general criteria of effectiveness and rules of optimization procedures.
- second, central optimization parameters are determined on the basis of a statistical planning analysis. This is treated as a first step in the iterative process of guiding the decentralized decisions.
- third, this iterative process is implemented on the basis of a traditional planning and counter-planning procedure, in which the center and the executive units act as a very large but very slowly working computer,
- fourth, to improve the convergence of the above iterative process various approaches are being tested:
  - the formulation of an iterative method of determining the central parameters, based on: traditional computation techniques, or on electronic computers,
  - the formulation of operations research models suited to the specific structure of decision-making problems facing particular administrative levels.

The discussion of some of the methods will be confined only to these techniques which were practically tested.

## 5.2. The Model of Optimization of Geographical Allocation of Foreign Trade. [1] (Assumptions, Formulation, Conclusions).

The general level and the commodity structure of final demand are pre-determined within the framework of the central planning procedure by the Central Planning Authority. [2] This planning procedure results in the determination of import requirement and export possibilities, which are transmitted to the Foreign Trade Ministry. Thus, for the Foreign Trade Ministry, the total amounts of imports and exports of a given commodity are the parameters of the system, and the volume of imports and exports of this commodity from or to particular markets are the systems' decision variables. Let us denote:

$Y_k^E$ — total exports of commodity k, as determined by the plan, on the export list comprising B items (in physical units);

$Y_k^I$ — total imports of commodity k, as determined by the plan, on the import list comprising R items (in physical units);

$y_k^{Er} \geq 0$ — exports of commodity k to market r in physical units;

$y_k^{Ir} \geq 0$ — imports of commodity k from market r in physical units;

s — the number of foreign markets.

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[1] W. Trzeciakowski: Model Optymalizacji Biezacej Polityki Kierunkowej (The Model of Optimization of Geographical Allocation of Foreign Trade in Gospodarka Planowa, No. 8-9, 1960, and in: Proceedings of the Regional Science Association, The Hague 1961, Edit. by W. Isard, New York, 1962.

[2] Problems of optimization of the commodity structure of foreign trade are discussed in the next chapter, where total export and import quotas become variables.

$r = 0$ the chosen market of the basic foreign currency.

We have thus: [ s + market 0] markets.

Hence:

$$\sum_{r=0}^{s} y_k^{Ir} = Y_k^I \quad \text{and} \quad \sum_{r=0}^{s} y_k^{Er} = Y_k^E$$

The Ministry of Foreign Trade--in order to allocate rationally planned imports and exports quotas has to:

— ensure balancing trade with separate markets at the planned level

— ensure the fulfillment of import targets at the cost of a minimum outlays on exports; the savings thus achieved of the export quota (as high as possible) can be used for additional imports from any chosen market, or for creating reserves of foreign currencies. It is obvious, that the choice of the currency in which one wants to create maximum reserve is dictated by the additional import possibilities which are available for that currency. Hence the most common choice will be the freely convertible currencies.

Denoting:

$d_k^{Er}$ export price f.o.b. of a physical unit of commodity k on market r expressed in the currency of market r ; these are prices actually obtained (or expected) for "our" commodities sold by

"our" exporters. [1]

$d_k^{Ir}$ import price c.i.f. of a physical unit of commodity $k$ on market $r$ expressed in the currency of market $r$ ; these are prices actually obtained (or expected to be paid) by "our" importers. [1]

$S^r$ planned balance of foreign trade with market $r$ (market 0 excepted) expressed in the currency of market $r$ ($S^r \gtreqless 0$).

$\pi_k^{Er}$ demand for "our" commodity $k$ on market $r$ . [2]

$\pi_k^{Ir}$ supply of commodity $k$ for "our"import on market $r$ .

$m$ the number of commodities.

Hence:

— the requirement of balancing trade with separate foreign markets takes the form:

$$\sum_{k=1}^{B} d_k^{Er} y_k^{Er} - \sum_{k=1}^{R} d_k^{Ir} y_k^{Ir} = S^r \qquad (r \neq 0)$$

the concept of a foreign currency market may mean, as well, an individual country with which separate foreign exchange accounts

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[1] It has to be stressed, in spite of some common beliefs, these are not "objective" prices of the "iustum precium" type, existing on some "ideal" foreign market, but effective prices paid and received by the country's foreign trade enterprises for its commodities. Substituting "potential" prices for "effective" prices would lead to "wishful-thinking planning."

[2] Due to the neglibible share of Polish foreign trade in World Foreing trade, we neglect the elasticities of foreign demand and foreign supply in connection with varying prices. The inclusion of elasticities would not affect our basic conclusions.

are made, as well as a group of countries, constituting a definite area of payments where unrestricted transferability of surpluses exist.

— the preference function: maximizing the surplus of the balance of trade with a chosen market, is written as follows:

$$\sum_{k=1}^{B} d_k^{Eo}\, y_k^{Eo} - \sum_{k=1}^{R} d_k^{Io}\, y_k^{Io} = \text{maximum}$$

— the constraints being:

$$0 \leq y_k^{Ir} \leq \pi_k^{Ir} \quad ; \quad \text{and} \quad 0 \leq y_k^{Er} \leq \pi_k^{Er} \quad ;$$

Thus, the task of the Ministry for Foreign Trade in the optimization of directions policy consists of such an allocation of foreign trade that leads to a maximization of the surplus of trade with a chosen market, while ensuring the fulfillment of planned import tasks with other markets, and fulfilling the requirements for balancing conditions on other foreign currency markets at a pre-determined level. The complete system is:

$$\sum_{r=0}^{S} y_k^{Ir} = Y_k^{I} \quad ; \qquad \sum_{r=0}^{S} y_k^{Er} = Y_k^{E} \quad ;$$

$$\sum_{k=1}^{B} d_k^{Er}\, y_k^{Er} - \sum_{k=1}^{R} d_k^{Ir}\, y_k^{Ir} = S^r \quad ;$$

$$0 \leq y_k^{Ir} \leq \pi_k^{Ir} \quad ; \quad 0 \leq y_k^{Er} \leq \pi_k^{Er} \quad ;$$

$$\sum_{k=1}^{B} d_k^{Eo}\, y_k^{Eo} - \sum_{k=1}^{R} d_k^{Io}\, y_k^{Io} = \text{maximum} \quad ;$$

The optimal solution takes into account: existing conditions (the available export quota, effective prices, demand and supply on foreign markets), given targets (import tasks, the required level of the balance of payment, the choice of the maximized foreign currency market) and Central Planners preferences of economic or non-economic nature (the acceptance of exports, imports, supply or demand on a given market at a predetermined level), if such preferences are to be introduced.

In principle the task of finding the optimal solution of that linear problem could be fulfilled at the Ministerial level by direct calculation. This, however, is not possible since the system has too many decision variables. As a realistically formulated over-all optimization problem would involve approximately 100,000 commodities to be allocated to approximately 3 - 100 currency areas, it may give rise to a linear program with several millions of possible variables subjected to hundreds of thousands of constraints. Such a problem is outside the possibilities of solution of any existing linear program computing code, the solution time for which increases approximately with the cube of the number of linear constraints. For these reasons, we confined research to the derivation of general rules of optimization that would enable individual foreign trade enterprises to take up their decisions at executive levels in a way consistent with the over-all effectiveness.

The general, non-numerical analysis of the properties of the optimal solution [1/] of the model formulated above proceded along the

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[1/] W. Trzeciakowski: "Problemy Kompleksowelo Systemu Analizy Efecktywnosci Biezacej Handlu Zagranicznego," Studia KPZK PAN Tom II, Warszawa 1961. At that time the works of Dantzig and Kantorowitch on decomposition were not known to Polish econometricians.

following lines:

let us introduce small changes in the optimal solution:

$$\Delta y_k^{Eo} \quad , \quad \Delta y_k^{Er} \quad , \quad \Delta y_k^{Io} \quad , \quad \Delta y_k^{Ir}$$

the increase of import (export) from (to) one market results in the decrease of import (export) from (to) another market:

$$\Delta y_k^{Io} = -\Delta y_k^{Ir} \; ; \; \Delta y_k^{Eo} = -\Delta y_k^{Er} \quad \ldots\ldots\ldots\ldots\ldots \qquad (1)$$

The balance of trade with the market $r$ has to remain intact, then:

$$d_k^{Er} \Delta y_k^{Er} - d_k^{Ir} \Delta y_k^{Ir} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

As we started from the optimal solution, the changes with the basic market can be either negative or neutral:

$$d_k^{Eo} \Delta y_k^{Eo} - d_k^{Io} \Delta y_k^{Io} \leq 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

From (1) and (2) we get:

$$-d_k^{Er} \Delta y_k^{Eo} + d_k^{Ir} \Delta y_k^{Io} = 0 \; ,$$

$$\Delta y_k^{Io} = \frac{d_k^{Er}}{d_k^{Ir}} \Delta y_k^{Eo} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (4)$$

Inserting (4) into (3) we get:

$$d_k^{Eo} y_k^{Eo} - \frac{d_k^{Io} d_k^{Er}}{d_k^{Ir}} \Delta y_k^{Eo} \leq 0$$

$$\Delta y_k^{Eo} \left( \frac{d_k^{Eo}}{d_k^{Er}} - \frac{d_k^{Io}}{d_k^{Ir}} \right) \leq 0 \; ; \quad \ldots\ldots\ldots\ldots\ldots \qquad (5)$$

To draw conclusions from the properties of the optimal solution, the following possibilities were analyzed:

— maximum export of commodity k : $y_k^{Er} = \min(\pi_k^{Er}, Y_k^E)$

— maximum import of commodity k : $y_k^{Ir} = \min(\pi_k^{Ir}, Y_k^I)$

— export within the boundaries: $0 < y_k^{Er} < \min(\pi_k^{Er}, Y_k^E)$

— import within the boundaries: $0 < y_k^{Ir} < \min(\pi_k^{Ir}, Y_k^I)$

Consider the case, where in the optimal solution a commodity is exported within the boundaries to market 0 and r , as well as imported within the boundaries from market 0 and r . In that case $\Delta y_k^{Eo}$ in (5) can be positive as well as negative. The expression (5) can be fulfilled only in the case when:

$$\frac{d_k^{Eo}}{d_k^{Er}} - \frac{d_k^{Io}}{d_k^{Ir}} = 0$$

$$\frac{d_k^{Eo}}{d_k^{Er}} = \frac{d_k^{Io}}{d_k^{Ir}} \overset{df}{=} K^r$$

Hence, in the optimal solution commodity k is exported within the boundaries to markets 0 and r and imported within the boundaries from these markets, when the ratio of export prices on these markets is equal to the ratio of import prices on these markets. This ratio $(K^r)$ will

be called the Directional Rate of Market $r$ .

Consider the next case, when in the optimal solution we have a maximum export of commodity $k'$ to market $r$ and export within the boundaries of that commodity to market $0$ ; we also have an import within the boundaries of commodity $k''$ from markets $0$ and $r$ .

Modifying (5) we get:

$$\Delta y^{Er}_{k'} \left(\frac{d^{Io}_{k''}}{d^{Ir}_{k''}} - \frac{d^{Eo}_{k'}}{d^{Er}_{k'}}\right) \leq 0$$

as: $\Delta y^{Er}_{k'} \leq 0$ then $\frac{d^{Io}_{k''}}{d^{Ir}_{k''}} - \frac{d^{Eo}_{k'}}{d^{Er}_{k'}} \geq 0$

hence: $\frac{d^{Eo}_{k'}}{d^{Er}_{k'}} \leq K^r$

Pursuing this analysis for further possible cases, we arrive at the following rule of optimal allocation which arranges consecutive foreign markets according to the value of the product $d^{E,Ir}_{k} K^r$ :

— exports of commodity $k'$ should fill successively foreign markets starting with that characterized by the highest product $d^{Er}_{k'} K^r$ , through consecutive markets ranged according to the decreasing value of the product $d^{Er}_{k'} K^r$ , until the export quota is exhausted;

— imports of commodity $k''$ should be allocated successively on foreign markets starting with that characterized by the lowest product $d^{Ir}_{k''} K^r$, through consecutive markets arranged according to the growing value of the product $d^{Ir}_{k''} K^r$, until the import quota is filled.

The set of $K^r$ expresses the ratios of individual currencies of market $r$ to the currency of market $0$, accepted as a basis ($K^o = 1$). The values of the set of directional rates $K^r$ ($r = 1, \ldots s$) should ensure that the balance of trade with market $r$ be equal to the planned value of $S^r$. Increasing the directional rate $K^r$ leads to the improvement of the balance of trade with market $r$; decreasing $K^r$ leads to opposite results. These properties can be used in the formulation of rules for the directional foreign trade policy.

Using the decomposition theorem [1] we arrive at important relationships connecting shadow prices of currencies $(K^r)$, shadow prices of commodities $(l_k)$ and foreign currency prices:

$$l_k \geq K^r d^{Er}_k \quad \text{when} \quad y^{Er}_k = 0$$

$$l_k = K^r d^{Er}_k \quad \text{when} \quad 0 < y^{Er}_k < \pi^{Er}_k$$

$$l_k \leq K^r d^{Er}_k \quad \text{when} \quad y^{Er}_k = \pi^{Er}_k$$

$$l_k \geq K^r d^{Ir}_k \quad \text{when} \quad y^{Ir}_k = \pi^{Ir}_k$$

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[1] G. B. Dantzig, P. Wolfe: "Decomposition Principle for Linear Programs" in Operations Research, 8 No. 1/1960. L. W. Kantorovich: Edonomicheski Roschot Nailutshevo Ispolzovania Resursov, Izdat Akademii Nauk SSSR, Moskwa 1960. J. Mycielski, K. Rey, W. Trzeciakowski: "Decomposition and Optimization of Short-Run Planning in a Planned Economy," Chapt. 2 in: Structural Interdependences in the Development Programming, Edited by T. Barna, Macmillan Co., London, 1962.

$$l_k = K^r d_k^{Ir} \quad \text{when} \quad 0 < y_k^{Ir} < \pi_k^{Ir}$$

$$l_k \leq K^r d_k^{Ir} \quad \text{when} \quad y_k^{Ir} = 0$$

The above relationships characterizing the optimal solution are helpful in the formulation of rules for the optimization procedures as well as for the practical determination of shadow prices of commodities (discussed in Part III). The directional rates $K^r$ can thus become a useful instrument of direct planning and indirect management, as:

- a set of central parameters enabling the comparison of commodity prices on various markets and thus making it possible to check directly the rationality of geographical allocation proposals.
- a set of central parameters guiding the balance of trade policy, either by way of plan-building prescriptions for executive levels, or by way of connecting the price policy results with an incentive system for enterprises. 1/

Primary directives concerning the allocation of basic commodity groups are dealt with first at the stage of construction of the central plan when the general volume and the commodity structure of foreign trade are determined; also central decisions concerning the allocation of basic commodity groups are taken up in a more specific manner at the stage of treaty agreements. However, once the basic proportions have been fixed,

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1/ Discussed in Part III.

there is a need for a general guidance of specific choices made by individual enterprises. These choices have a marginal character and have to take into account the general set up determined by the primary decisions. The individual enterprise knows the range of possible foreign trade choices within the sphere of its own commodity list, but it ignores all alternatives outside its own field of interest. Therefore, the general information given by the central planner in the form of a set of marginal directional rates for foreign markets is of paramount importance for guiding the decentralized decisions taken up by enterprises. The broader the sphere of decentralized decision-making in foreign trade, the more importance attaches the central planner to the instruments of indirect management.

5.3. Alternative Ways of Determining the Directional Rates.

The Central Planner must now face the crucial problem of how to determine in practice the directional rates. In theory, two possible approaches are to be considered:

1. either to determine $K^r$ on the basis of a statistical analysis of the solution existing in reality. The results of this analysis can eventually be corrected on the basis of a planning analysis and then applied to traditional procedures of planning and counter planning
2. or to compute $K^r$ on the basis of a computational optimization procedure, either central or decomposed.

The second approach has been much more appealing, if it were feasible in practice. However, it has been found impossible for the following reasons:

a. The magnitude of the problem ruled out any meaningful attempts to use algorithms of the Simplex type.

b. Even if such computational algorithms were developed, that could be able to compute linear programs of that magnitude, the collection of planning information necessary to feed the computer would create unsurmountable difficulties. This information is not known in advance; it is being discovered in the course of the negotiating process; many treaty agreements and the resulting commodity prices and quantity constaints are the outcome of "tie-in-sale" arrangements, leading to stochastic supply and demand functions, which could not be incorporated into the over-all model "ex ante." The collection of information is a constant process and prices and constraints are changing over time.

c. Experience has shown, that the reliance on a plannistic over-all model without a detailed knowledge of all important information leads to far worse results, than deriving $K^r$ from statistical data. As a rule, it was leading to unfeasible solutions, which were impossible to be computationally improved, because of the magnitude of the information system involved.

This explains why the second solution had to be abandoned in the first stage of practical application and why most efforts were concentrated on developing the techniques suited to the first approach (see Part III: statistical and plannistic methods of determining marginal rates).

Though one could argue that the existing solution taken as a basis may be far from the optimum, or that the future conditions of foreign trade may deviate from the actual ones--still the reliance on past overall statistical data proves to be better, as all detailed information on prices, constraints, tie-in-sale arrangements, etc. are in it. This explains why the "traditional" method of planning and counter planning is being used, and why traditional statistical and graphical methods of determination of shadow rates are--as by now--the only realistic alternative.

5.4. The Search for Computational Optimization Methods.

Hard necessities of meeting the demands of the Central Planner for simple and immediately applicable solutions did not eliminate intellectual temptations to find out some computable algorithms that would, at least, help the traditional approach in improving its convergence.

To be able to determine the optimal values of $K^r$ the following iterative procedure was first suggested: [1/]

1. We determine the initial set of $K^r$ on the basis of a statistical analysis of foreign trade, using the transformed Paasche's formula:

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[1/] W. Trzeciakowski: "Model Optymalizacji Biezacej Plityki Kierunkowej W Handlu Zagranicznym," Gospodarka Planowa, No. 8-9, 1960. Warszawa. As can easily be seen, the approach accepted in determining the set of $K^r$ has little in common with the concept of "purchasing power parity" rates.

$$K^r = \frac{1}{2}\left[\frac{\sum_{k'} d_{k'}^{Eo} Y_{k'}^{E}}{\sum_{k'} d_{k'}^{Er} Y_{k'}^{E}} + \frac{\sum_{k''} d_{k''}^{Io} Y_{k''}^{I}}{\sum_{k''} d_{k''}^{Ir} Y_{k''}^{I}}\right]$$

(The index obtained was determined as the "Index of Relative Value of Currency r")

2. We arrange exports according to the decreasing values of the products $d_{k'}^{Er} K^r$, and imports according to the increasing values of the products $d_{k''}^{Ir} K^r$, taking into account existing constraints on consecutive markets $r$.

3. We balance exports and imports on each market. The difference between the resulting balance and the planned $S^r$ is obtained, as the "unplanned deviation" (positive or negative).

4. If the "unplanned deviation" is negative, we increase $K^r$. If the "unplanned deviation" is positive, we decrease $K^r$.

5. We repeat the procedure (2) - (4) with seccessive values of $K^r$ until the "unplanned deviations" become negligible.

The original numerical illustration of the method suggested is described in Appendix. The attractiveness of the approach lies in its simplicity. The solution of the example has been reached in the course of nine iterations relying on simple arithmetic. The same example using the Simplex Method would require a computer solving 59 equations with 88 unknowns.

However, the intuitive character of the method suggested could be looked upon as its weakness. As, indeed, there was no explicit formula on how the consecutive values of $K^r$ should be determined. In a very

large computational program it could easily occur that increasing or decreasing some $K^r$ too much would cause in that iterative step a possible deterioration of the preference function value.

In an attempt to improve the intuitive method suggested above, Tom Kronsjö employed the same approach of iterative currency prices, but complemented it with a special process for calculating the successive iterations. 1/ The Kronsjö approach has been indeed a theoretical improvement, as it ensured the convergence of consecutive iterative steps. However, applied to solving optimization problems of approximately 3,000 commodities and 40 markets, it often encountered "oscillatory bottlenecks" which prevented the computer from reaching any finite solution. Then the procedure had to be stopped, and some small changes had to be introduced into theprogram so as to enable the computer to reach a solution. Though this computer-man-computer procedure was not "elegant," it did not affect the reliability of the solution, as the changes introduced into the program were economically insignificant. This approach has been practically and successfully checked on statistical data dealing with past series. However, the weak point of the procedure was a very slow convergence.

In an attempt to improve the convergence of the iterations, J. Mycielski developed further the "computer-man-computer" approach.

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1/ See T.O.M. Kronsjö: "Iterative Pricing for Planning Foreign Trade," in Economics of Planning, Vol. 3, No. 1, 1963.

J. Mycielski and H. Maciejewski formulated a speedy converging algorithm, that could solve allocation problems of 3,000 commodities but only for three markets (or rather geo-political regions). This gave a possibility to check the general propositions of the aggregated regions' directional rates and hence check the correctness of the traditional approach used. Attempts to enlarge this algorithm to 40 markets were unsuccessful. It seems, that the future development of the system of geographical allocation, can be further improved along the following lines:

— aggregated operations research calculations of an over-all geographical allocation at the central level should be adopted to the existing system of information disposable at this level. At this stage, a limited number of markets and a very restricted number of basic commodities and an aggregated "non-specified" group could be used, as a "first guess" of the central planner. This step compared to the results of the statistical solution could offer a valuable contribution to a better final-value judgement of experts.

— a specific operational model suited to the elaboration of an individual treaty with a given market should be constructed and practically tested at the central level. It should deal first with the information available for the traditional decision-making process and there it could gradually enlarge the scope

of information processed. This should lead to a constant improvement of the partial solutions, and hence contribute to the improvement of the over-all solution.

— simple optimization procedures for the enterprise level should be prescribed, as an attempt to speed the convergence of the system. These procedures, based on the original reasoning explained earlier, have been recently worked out by A. Legatowicz.[1/] They contribute to the original method a rule of convergent determination of $K^r$ through a successive determination of commodity shadow prices.

In general, all these partial optimization processes have to be constantly reconciled by the Central Planner, in the course of a traditional planning dialogue between the center and the various decision-making sub-centers.

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[1/] A. Legatowicz: "Methods of Determination of Directional Rates and Commodity Shadow Prices," J.K.i.C. -- to be published 1971. These methods are at their experimental stage.

Appendix to Chapter 5.

Numerical Illustration of the Iterative Method of Determination of $K^r$.

Let us take 11 commodities (or aggregated commodity groups). Six of them are exported ($E_k$), five imported ($I_k$). The number of market let be four: r = 0, 1, 2 and 3 . We postulate, that the balances of trade $\lambda_r$ be: $\lambda_1 = 0$ ; $\lambda_2 = +1$ ; $\lambda_3 = -16$ ; $\lambda_o$ = maximum.

Table 1 presents the initial data:

| Parameters \ Commodities | $E_1$ | $E_2$ | $E_3$ | $E_4$ | $E_5$ | $E_6$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Y_k^E$ , $Y_k^I$ | 1,5 | 3 | 2 | 7 | 1 | 5 | 2,5 | 4 | 1 | 8 | 6 |
| $\pi_k^{E1}$ , $\pi_k^{I1}$ | 2 | 0 | 1 | 0 | 0,5 | 7 | 1,5 | 5 | 1 | 0 | 2 |
| $\pi_k^{E2}$ , $\pi_k^{I2}$ | 0 | 1,5 | 0,5 | 5 | 1 | 10 | 0,5 | 1 | 2 | 3 | 4 |
| $\pi_k^{E3}$ , $\pi_k^{I3}$ | 0 | 5 | 1 | 15 | 0 | 0 | 2 | 0 | 0,5 | 7 | 10 |
| $\pi_k^{Eo}$ , $\pi_k^{Io}$ | 1 | 2 | 0 | 14 | 0,3 | 4 | 4 | 13 | 5 | 10 | 0 |
| $d_k^{E1}$ , $d_k^{I1}$ | 1 | 0,2 | 1 | 0,1 | 1,5 | 1 | 1 | 0,2 | 2,6 | 0,2 | 1 |
| $d_k^{E2}$ , $d_k^{I2}$ | 2 | 1,5 | 4 | 0,4 | 3 | 3 | 1,5 | 0,7 | 8 | 2 | 2 |
| $d_k^{E3}$ , $d_k^{I3}$ | 25 | 10 | 30 | 2 | 60 | 15 | 18 | 5 | 90 | 11 | 30 |
| $d_k^{Eo}$ , $d_k^{Io}$ | 3 | 1 | 2 | 0,5 | 8 | 2 | 2 | 1 | 7 | 1 | 2 |

Using the formula for $K^r$ we get at the start: $K^1 = 2.795$ ; $K^2 = 0.88$ ; $K^3 = 0.102$ ;

Table 2: Comparable Prices

| $d_k^{Er}\ K$ , $d_k^{Ir}\ K^r$ | $E_1$ | $E_2$ | $E_3$ | $E_4$ | $E_5$ | $E_6$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $d_k^{E1}\ K^1$ , $d_k^{I1}\ K^1$ | 2.795 | - | 2.795 | - | 4.19 | 2.795 | 2.795 | 0.559 | 7.18 | - | 2.795 |
| $d_k^{E2}\ K^2$ , $d_k^{I2}\ K^2$ | - | 1.32 | 3.52 | 0.352 | 2.64 | 2.64 | 1.32 | 0.616 | 7.04 | 1.76 | 1.76 |
| $d_k^{E3}\ K^3$ , $d_k^{I3}\ K^3$ | - | 1.02 | 3.06 | 0.20 | - | - | 1.84 | - | 9.18 | 1.12 | 3.06 |
| $d_k^{Eo}$ $d_k^{Io}$ | 3 | 1 | - | 0.5 | 8 | 2 | 2 | 1 | 7 | 1 | - |

$k^o = 1$

Ranging commodities in accordance with increasing or decreasing comparable prices ($d_k^{E,Ir}$ $K^r$) and allocating accordingly on consecutive markets (considering constraints on foreign supply and foreign demand), we arrive at the first iteration of allocation proposals:

| $Y_k^{Er}$ , $Y_k^{Ir}$ | $E_1$ | $E_2$ | $E_3$ | $E_4$ | $E_5$ | $E_6$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Y_k^{E1}$ , $Y_k^{I1}$ | 0,5 | - | 0,5 | - | 0,5 | 5 | - | 4 | - | - | 2 |
| $Y_k^{E2}$ , $Y_k^{I2}$ | - | 1,5 | 0,5 | - | 0,2 | - | 0,5 | - | - | - | 4 |
| $Y_k^{E3}$ , $Y_k^{I3}$ | - | 1,5 | 1 | - | - | - | 2 | - | - | - | - |
| $Y_k^{Eo}$ , $Y_k^{Io}$ | 1 | - | - | 7 | 0,3 | - | - | - | 1 | 8 | - |

The "unplanned deviations" in the balance of trade calculated on the basis of the formula:

$$\alpha_r = \sum_{k=1}^{6} y_k^{Er} \, d_k^{Er} - \sum_{K=1}^{5} y_k^{Ir} \, d_k^{Ir} - \lambda_r$$

give the following results:

$\alpha_1 = + 3.93$ $\qquad$ $\alpha_3 = + 25$

$\alpha_2 = - 4.90$ $\qquad$ $\alpha_{\cdot} = - 6.1$

Hence we decrease $K^1$, increase $K^2$ and decrease $K^3$. Repeating the above steps we get the next iterations. After nine iterations, we obtained

the following results:

$$K^1 = 2.73 \; ; \quad K^2 = 0.91 \; ; \quad K^3 = 0.091 \; ; \quad \lambda_o = + 2.62$$

A "blind allocation" concerned only with balancing foreign trade without paying attention to the corporative prices gave $\lambda_o = - 11.8$ . Hence, the method gave an improvement of 14.42 units, i.e. 44% of the value of total export expressed in currency 0.

## 6. The Model of Short-Run Optimization of the Volume. Commodity Structure and Geographical Allocation of Foreign Trade.

### 6.1. The General Approach and the Basic Assumptions.

The next task that faced the planners was the formulation of effectiveness criteria of foreign trade. It became evident that individual effectiveness indicators constructed independently from each other were mutually inconsistent. Hence the practical task put by the Central Planner was the mathematical verification of the correctness of effectiveness indicators applied in the late fifties. It has to be stressed that at that time the decomposition algorithms of Kantorovich and Dantzig Wolfe were not known to Polish economists.

The reasoning underlying the formulation of optimization models has to start with a description of decision-making processes applied in existing planning and management systems. Some accepted solutions may be typical only for specific stages of the development of the decision-making system and hence they need not be looked upon as a characteristic feature of central planning, others may be deeply rooted in the logic of the functioning of a centrally planned economy. In the traditional system of planning and management of the late fifties domestic costs and prices have been deliberately separated from foreign prices. Hence the level of domestic prices did not directly affect the level of export prices expressed in foreign currency. There was no uniform rate of exchange and, consequently, neither was there any automatic regulation of this rate through any economic mechanism. If one wants to rely on a descriptive

approach, this separation of domestic costs from foreign prices would be taken as a characteristic feature of the existing system of planning and management. However, if this need not be the case, if the task of the analysis is to improve actual decision-making processes, then a normative, prescriptive approach should be used. The initial model should then rely only on basic assumptions underlying decision-making in a centrally planned economy and then the resulting conclusions may be compared with the existing solutions in order to check their feasibility.

In a centrally planned economy primary , general decisions taken up at the central level, pre-determine the choice of detailed solutions made at lower decision-making levels. Therefore, planning of foreign trade has to be looked upon as an integral part of the overall system of short-run planning. Consequently, the initial, basic model of foreign trade optimization should be identical to the general model of optimization of short-run planning.

Short-run foreign trade planning has two main purposes:

— to ensure the growth of the national economy by covering the needs of this economy in necessary imports;

— to lower the social outlays of labour required to reach the planned level and structure of national income, by making available the advantages of the international division of labour.

In the first case, the structure of exports is determined by commodity balances while the directions structure of those exports is determined by balances of payments with separate foreign currency markets. That is why,

one is here interested only in ensuring the internal consistency of the plan from the point of view of the balance of commodities and the balance of payments, and not in optimizing the commodity and the directions structure of foreign trade.

In the second case the situation is different, since besides ensuring necessary imports, foreign trade is confronted with the task of lowering the social outlays of labour, required to reach the planned level of national income, by ensuring the advantages of the international labour division. With such a purpose in view, one is interested not only in balancing commodities and payments, but also in optimizing the size, structure and directions of foreign trade. Thus, an over-all model of the current optimization of foreign trade simultaneously presents a model of the balance of the whole economy. Optimization criteria derived from such a model ensure the subordination of the size, structure and directions of foreign trade to the requirements of the general and basic targets accepted by the central planner.

In short-time periods the actual possibility of choice in foreign trade amounts to the choice of an optimum set of commodities, according to available raw materials and the capacities of individual plants, and according to the optimization of the directions of exports and imports within the existing field of directions manoeuvre.

The central planning authority determines the tasks of the plan, and it is only this authority that knows the conditions of the economy as a whole, on which effective fulfillment of the target is dependent. Not

all decisions, however, can be made at the cental level. In practice, the planning authority has a limited knowledge of the detailed parameters of the optimization calculation. For this reason many decisions on the allocation of resources must be taken at various executive levels, where detailed information on technological relationships, capacity limitations, alternative applications of this capacity and of raw materials for the production of various commodities is available.

It is highly desirable to decentralize certain sectoral decisions in foreign trade where there is an additional difficulty in planning: i.e. the impossibility for influence, by the central planner of such external parameters as the calculation of foreign prices, or supply and demand on foreign markets. Fluctuations of these parameters occur much more quickly than the making of decisions, at central level, on the structure and directions of foreign trade. This can easily lead to irrational decisions. The central planning authority must then partly transfer its competence to enterprises of foreign trade and to producing enterprises, although to ensure, that the decisions of these enterprises are made in accordance with the requirements of the general economic situation, central instructions must be available, to ensure the fulfillment of the plan in a most effective way from the point of view of the economy as a whole. Apart from detailed directives of the plan, such a central instruction may include the general criterion of effectiveness, containing synthetic optimization parameters. These parameters are established by the central authority on the basis of overall calculations, and they take into account

current preferences of economic policy. Thus, the basic task in the system of analysis of current effectiveness consists of introducing workable criteria of effectiveness for the construction of short-run plans of foreign trade at the central level, and criteria for the optimization of export and anti-import production at the executive level.

The starting point of the formulation of the model is the necessity of satisfying final demands in consumption and investment, as determined in the central plan, with a minimizing of outlays of labour in the economy. The possibility of satisfying these final demands either through domestic output, or through imports is considered /stocks and reserves are included in final demand/. This amounts to saying, that the structure and the level of national income as determined in the central plan of development are taken as directive initial data, determining the optimization in the choice of the remaining parameters, which are treated as secondary. Thus the task can be reduced to determining the output of separate commodities and the foreign trade in those commodities at levels which will satisfy final demands as determined by the plan with the minimum outlay of social labour. If the problem is thus formulated the task put forth by the central planner is accepted as a directive, creating at the same time a rational basis of evaluating /ex post/, whether the initial tasks were determined correctly from the point of view of criteria which are not directly involved in the model/e.g. the postulate of full employment, of the equilibrium of the financial plans etc/. Outlays of social labour in the minimized expression are measured in man-hours multiplied by existing wage-rates.

The calculation of labour outlays in the model does not include amortization. In the aspect of current calculation, since investment outlays on existing capacities have already been made in the past, the level of amortization is not dependent on the degree or the way in which these capacities are engaged in production. For this reason amortization cannot influence decisions on optimal choice.

The model suggested was based on techniques of linear programming and on the assumption of constant technical coefficients. This means then that changes in the cost level as a function of the scale of production and the influence of elasticity of supply and demand on the optimization calculation are not accounted for.

Thus criteria derived from the model can only be applied to current problems of foreign trade, and they are not adequate for solving problems of the evaluation of the international division of labour over longer periods /perspective plans/, in which investment in time must be considered.

The tasks of the central planner, however, consist not only in the determining of final demands, but also of determining, a priori, certain levels of outputs, imports and exports, which limit or correct the range of the optimization calculation of the international division of labour, owing to:

1. the necessity of ensuring the domestic industrial base for development and for the protection of constant economic growth from external influences, determining the right proportions of growth and making it independent from world trade cycles, fluctuations etc.
2. the necessity of including 'protectionist' provisions in de-

veloping branches of the economy, in which present domestic labour productivity is low, but which will reach the world level of productivity, once they work at full capacity,

3. the necessity of taking into account preferences of current state policy on employment, international obligations, economic equilibrium etc.

In all such cases outputs, imports and exports are included in the system at predetermined levels.

## 6.2. The Model of Optimization of the Volume and the Commodity Structure of Foreign Trade with One Single Foreign Market and No Limitations Among Commodities.

First, a model based on the following simplifying assumptions has been constructed:

- there exists only one single foreign market abroad; the turnovers with that market have to be balanced;
- outputs of separate commodities, not production activities are considered;
- all commodities are independent from each other.

The following notations were used:

$P_k$ - domestic demand for commodity k (for consumption or investment) in physical units.

$x_k$ - the level of production of commodity k in physical units.

$y_k^E$ - exports of commodity k in physical units.

$y_k^I$ - imports of commodity k in physical units.

$d_k^E$ - export price f.o.b. of a physical unit of commodity k expressed in foreign currency.

$d_k^I$ - import price c.i.f. of a physical unit of commodity k expressed in foreign currency.

$b_k$ - maximum capacity of production of commodity k in physical units.

$\pi_k^E$ - demand for commodity k exported abroad in physical units.

$\pi_k^I$ - supply of commodity k imported from abroad in physical units.

$C_k^*$ - complet outlays of live labour costs necessary to produce a T* (as above $C_k^*$) unit of commodity k and measured in man-hours multiplied by existing domestic wage rates.

n - the number of commodities (k = 1, ..., n).

Thus:

The requirement of satisfying the final demands takes the form:

$$x_k + y_k^I - y_k^E = P_k \qquad (k = 1, \ldots, n).$$

The balance of foreign trade takes the form:

$$\sum_k d_k^E y_k^E - \sum_k d_k^I y_k^I = 0$$

The constraint:

$$0 \leq x_k \leq b_k \quad ;$$

$$0 \leq y_k^E \leq \pi_k^E \quad ;$$

$$0 \leq y_k^I \leq \pi_k^I \quad ;$$

The preference function:

$$\sum_k C_k x_k = \text{minimum} .$$

The analysis of the properties of the optimal solution runs as follows:

$$x_k = P_k + y_k^E - y_k^I \ ;$$

$$\sum_k d_k^E y_k^E - \sum_k d_k^I y_k^I = 0$$

$$y_k^E \geq 0 \ ; \quad y_k^I \geq 0 \ ; \quad y_k^E \leq \pi_k^E \ ; \quad y_k^I \leq \pi_k^I \ ; \quad P_k + y_k^E - y_k^I \geq 0$$

$$(y_k^E - y_k^I \leq b_k - P_k) \ ; \quad y_k^I - y_k^E \geq P_k - b_k \ ;$$

eliminating $\sum_k T^* P_k$ we get: $\sum_k C_k^* y_k^E - \sum_k C_k^* y_k^I = \text{minimum}$ .

We introduce:

$$M_k^E \overset{df}{=} \frac{C_k^*}{d_k^E} \ ;$$

$$M_k^I \overset{df}{=} \frac{C_k^*}{d_k^I} \ ;$$

as $d_k^I > d_k^E$ we have: $M_k^E > M_k^I$ ;

The inequalities can be transformed [1] into:

$$0 \leq y_k^E \leq \min(\pi_k^E , b_k - P_k) \ \mathbf{E}(b_k - P_k \geq 0)$$

---

[1] Using the property of the optimal solution that: $y_k^E \cdot y_k^I = 0$ (i.e. that in the optimal solution we have either export or import.)
Proof: Let us assume that in the optimal solution there exists a commodity $k'$ , which is being exported and imported: $y_{k'}^E > 0$ and $y_{k'}^I > 0$ . Introducing small changes, we may get: $\Delta y_{k'}^E = \Delta y_{k'}^I < 0$ ; the change in the balance of trade is: $\Delta y_{k'}^E (d_{k'}^E - d_{k'}^I) > 0$ . The balance of trade improved though the domestic costs remained unchanged; Hence the initial solution was not optimal.

$$\max(0,\ P_k - b_k) \leq y_k^I \leq \min(\pi_k^I,\ P_k)$$

$$y = f(x) = \varepsilon(x \geq 0) = \begin{cases} 1 \text{ where } x \geq 0 \\ 0 \text{ where } x < 0 \end{cases}$$

a. $y$ is determined when the left and right side of the inequalities are equal.

b. $y$ is not strictly determined when both sides of the inequality differ; then - $y$ can be "minimal" (i.e. equal to the lower bound).

- $y$ can be "medium" (i.e. between the lower and upper bound).

- $y$ can be "maximal" (i.e. equal to the upper bound).

provide: $\pi_k^I \geq P_k - b_k$

The properties of the optimal solution are formulated on the basis of the analysis of all possible permutations of the above cases.

1. Suppose there is a "medium" export of commodites k' and k" . If export of k' were increased by $\Delta y_{k'}^E$, then the foreign trade balance equation requires decreasing export of k" by $\Delta y_{k"}^E$ :

$$d_{k'}^E \Delta y_{k'}^E + d_{k"}^E \Delta y_{k"}^E = 0$$

$$\Delta y_{k"}^E = - \frac{d_{k'}^E}{d_{k"}^E} \Delta y_{k'}^E ;$$

The corresponding change in domestic costs will be:

$$C^*_{k'}\ \Delta y^E_{k'} + C^*_{k''}\ \Delta y^E_{k''} \geq 0 \qquad \text{[as we changed the optimal solution]}$$

$$C^*_{k'}\ \Delta y^E_{k'} - \frac{d^E_{k'}}{d^E_{k''}}\ C^*_{k''}\ \Delta y^E_{k'} \geq 0 \qquad : d^E_{k'}$$

$$\Delta y^E_{k'}\ (M^E_{k'} - M^E_{k''}) \geq 0$$

as $\Delta y^E_{k'} \gtrless 0$ then $M^E_{k'} - M^E_{k''} = 0$ hence $M^E_{k'} = M^E_{k''} \overset{df}{=} M^E$

In the optimal solution export of $k'$ and $k''$ is "medium" when

$$\underline{M^E_{k'} = M^E_{k''} \overset{df}{=} M^E}$$

2. Suppose there is a "maximal" export of $k'$ and a "medium" export of $k''$.

Hence: $\Delta y^E_{k'} < 0$;

as $\Delta y^E_{k'}\ (M^E_{k'} - M^E_{k''}) \geq 0$ then $(M^E_{k'} - M^E_{k''}) \leq 0$

hence $M^E_{k'} \leq M^E_{k''} = M^E$; $\underline{M^E_{k'} \leq M^E}$

3. Suppose there is a "medium" export of $k'$ and a "medium" import of $k''$;

The foreign trade balance equation requires that:

$$d^E_{k'}\ \Delta y^E_{k'} - d^I_{k''}\ \Delta y^I_{k''} = 0 \quad \text{hence} \quad \Delta y^I_{k''} = \frac{d^E_{k'}}{d^I_{k''}}\ \Delta y^E_{k'}$$

As the changes were introduced in the optimal solution, they must increase costs:

$$c_k^*, \Delta y_{k'}^E - c_k^*, \Delta y_{k''}^I \geq 0$$

$$\Delta y_{k'}^E (M_{k'}^E - M_{k''}^I) \geq 0$$

$$M^E = M_{k'}^E = M_{k''}^I = M^I$$

$$M^E = M^I \stackrel{df}{=} M$$

This type of analysis is applied to other possible permutations of maximal, medium and minimal export and import. Using the rules:

$$(a \rightarrow b) \rightarrow (b' \rightarrow a')$$

we arrive at the following conclusions:

| 1 | 2 | 3 |
|---|---|---|
| $M_k^E > M_k^I > M$ | $M_k^E > M_k^I = M$ | $M_k^E > M > M_k^I$ |
| $y_k^E = 0$<br>$y_k^I = \min(\pi_k^I, P_k)$ | $y_k^E = 0$<br>$\max(0, P_k - b_k) \leq y_k^I \leq \min(\pi_k^I, P_k)$ | $y_k^E = 0$<br>$y_k^I = \max(0, P_k - b_k)$ |

| 4 | 5 |
|---|---|
| $M_k^E = M > M_k^I$ | $M > M_k^E > M_k^I$ |
| $0 < y_k^E < \min(\pi_k^E, b_k - P_k) \cdot \varepsilon(b_k - P_k \geq 0)$<br>$y_k^I = \max(0, P_k - b_k)$ | $y_k^E = \min(\pi_k^E, b_k - P_k) \cdot \varepsilon(b_k - P_k \geq 0)$<br>$y_k^I = \max(0, P_k - b_k)$ |

provided: $\pi_k^I \geq P_k - b_k$

and safeguarding: $\sum_k d_k^E y_k^E - \sum_k d_k^I y_k^I = 0$

The economic interpretation of the results is the following:

In the first sector there is no export; Imports are maximal;

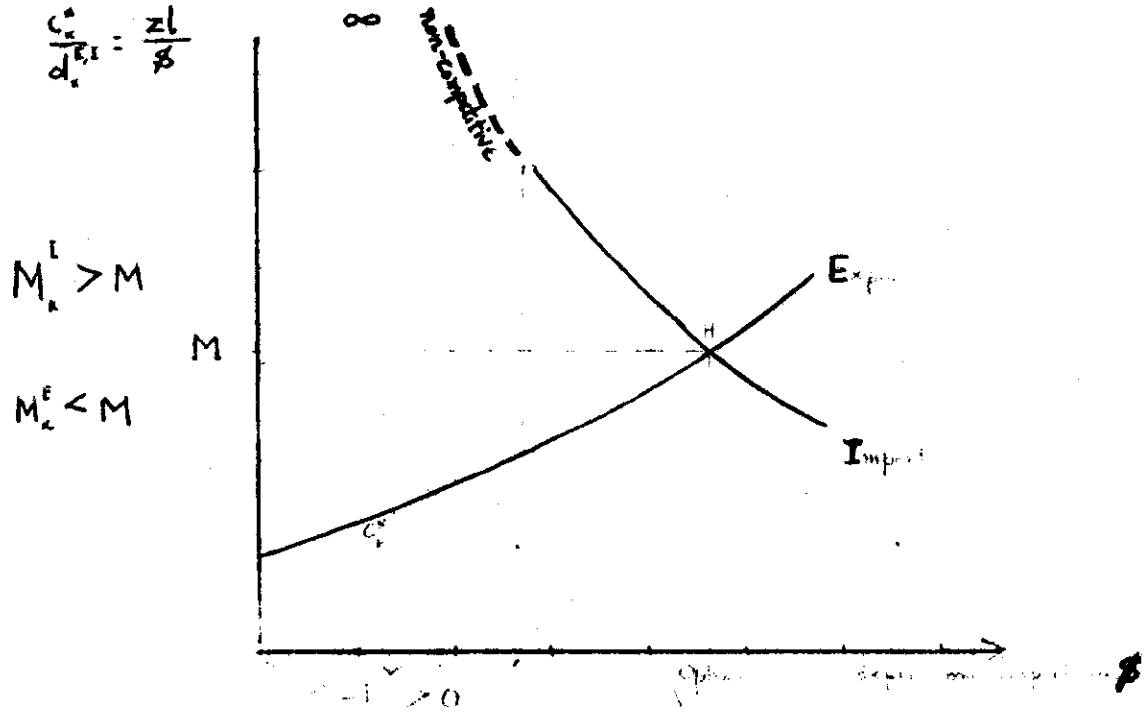
In the second sector there is no export; It is indifferent whether to produce or to import;

In the third sector there is no export; Import is minimal, i.e. as much as is indispensible;

In the fourth sector export is "medium," import is minimal, i.e. as much as is indispensible;

In the fifth sector export is "maximal," import is minimal.

The graphical illustration of the conclusions is the following:



In the optimal solution, there exists a marginal rate of effectiveness M ; This rate is determined by the over-all balance of foreign trade and limits marginal domestic costs paid for a unit of foreign currency. At this point, the volume of exports and imports is optimum and the gains from foreign trade are maximum.

To prove the limited value of using the indicators of effectiveness of the quotient form, it was necessary first to show the spheres where their use was fully correct. This was the aim of the above analysis: where the initial assumptions of the model hold--it is justified to use the effectiveness criteria:

$$M_k^E \leq M ; \quad M_k^I \geq M ;$$

The above criteria can be applied as an instrument of decentralized decision-making in all these cases where the assumption of no mutual limitations among commodities is justified.

## 6.3. The Model of Optimization of the Volume and Commodity Structure of Foreign Trade with One Foreign Market.

### The First Emergence of the Profit Criterion.

The aim of that model analysis was to determine effectiveness criteria for decentralized decision-making in short-run planning and current management, still keeping the simplifying assumption of the existence of a single foreign market, but dropping out the assumption of the lack of mutual limitations. Therefore, some additional notation is necessary:

$S$ - planned balance of trade with the foreign market ($S \gtreqless 0$)

$c_k$ - unit domestic cost of the last phase of processing commodity $k$ (inclusing labour costs only and exclusing costs of raw materials and amortization).

$a_{ij}$ - technological coefficient.

$a_{kk} = 1$ ; $a_{kj} \leq 0$ when $k \neq j$

Hence, $a_{kj}$ for $k \neq j$ is the amount of commodity $k$ used for the production of a unit of commodity $j$ in the final production phase, taken with a " - " sign. Then:

$\sum_{j=1}^{n} a_{kj} x_j$ is the final production of commodity $k$

$(a_{kk} x_k + \sum_{\substack{j=1 \\ j \neq k}}^{n} a_{kj} x_j)$ ;

$\hat{0}$

Thus, the former model takes the following form:

$$\sum_{j=1}^{n} a_{kj} x_j + y_k^I - y_k^E = P_k$$

$$\sum_{k=1}^{n} d_k^E y_k^E - \sum_{k=1}^{n} d_k^I y_k^I = S$$

$$0 \leq x_k \leq b_k \qquad (k = 1, \ldots, n)$$

$$0 \leq y_k^E \leq \pi_k^E$$

$$0 \leq y_k^I \leq \pi_k^I$$

$$\Sigma c_k x_k = \text{minimum}$$

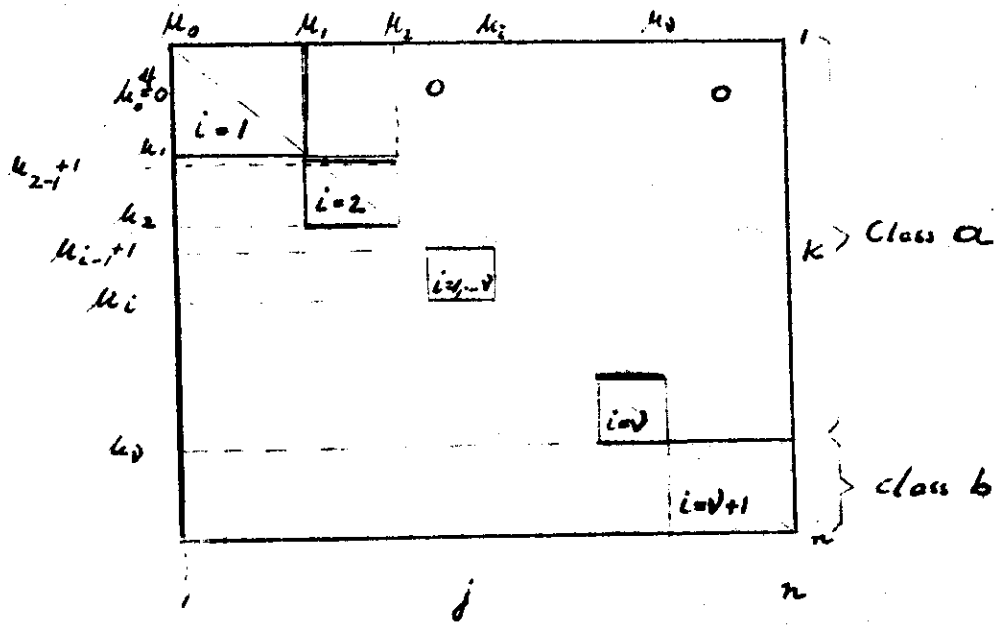
As already mentioned the decomposition approaches of Kantorovich and Dantzig-Wolfe were not known at the time of elaboration of these models. Hence a method has been suggested that takes into account only the most crucial interdependencies among various commodities, which occur within the so-called "groups of interrelated activities." The remaining interdependencies are taken into account only in terms of costs.

It has been assumed, that all commodities can be divided into two classes: "a" and "b".

Class "a" consists of commodities that are interrelated among certain groups only. These are no interrelationships outside groups. Commodities pertaining to class "a" are not raw materials for commodities pertaining to class "b".

Class "b" consists of commodities which are not limiting the production of any other commodities.

The approach accepted can be illustrated by the following scheme:




The groups of interrelated activities (class a) to be useful in practice should not be too large, so as to enable operations research calculations. But the main problem lies in basic raw materials, like electricity, fuels, steel, etc. which connect the whole economy into such large groups, that any operations research calculation becomes unfeasible. Therefore we were trying to enumerate such cases, which include either measurable limitations or non-limited supplies of raw materials. The following categories were created as a priori assumptions for pricing:

1) The increase in the demand for a raw material will be supplied from domestic production (either because there exist well known in advance foreign trade constraints on the supply of that material, or because import is unprofitable, or because the state intends to develop the domestic productive capacities of that material.

2) The increase in the demand for a raw material is negligible, so that it will not limit in an essential way the use of that material in other sectors (e.g. the increase in the production of watches will not affect the steel quotas for the construction--and ship building industries.
3) The increase in the demand for a raw material will be covered by increased imports of that material.
4) The increase in the demand for a raw material will be covered by the decrease of existing experts of that material.

In practice, these assumptions cover an essential share of all these cases which are important in reality.

On the basis of the above assumptions it is possible to transform the general optimization model into a formally analogous optimization problem of the structure presented in the scheme shown above.

In the matrices $(a_{kj})$ only those technical coefficients remain unchanged which are dealing with the productive use of a commodity pertaining to class a for another commodity pertaining to the same group of interrelated activities. Other technical coefficients of commodities belonging to class a and all other coefficients of commodities belonging to class b are equal 0, except the matrix diagonal, equal to unity.

Hence

$$a^{+}_{kj} = \begin{cases} a_{kj} & \text{when } \mu_{i-1} < k, j \leq \mu_i \text{ for } i = 1, \ldots, \nu, \text{ hence for class a} \\ \delta_{kj} & \text{for the remaining } k, j \end{cases}$$

where

$$\delta_{kj} \overset{df}{=} \begin{cases} 1 & \text{for } k = j \\ 0 & \text{for } k \neq j \end{cases}$$

In the minimized preference function the processing cost $c_k$ is being replaced:

-- for commodities belonging to class "b" by $c_k^*$ i.e. by the complete outlays of live labor costs necessary to produce a unit of commodity $k$ [1]

-- for commodities belonging to class "a", by the difference between the complete outlays $c_k^*$ and the sum of all complete outlays of labor used for raw materials pertaining to the same group of interrelated commodities. It is thus the processing cost of the last phase plus the complete cost of raw materials from class b, necessary in the last phase.

Hence:

$$c_k^+ = \begin{cases} \sum_{j=\mu_{i-1}+1}^{\mu_i} c_j^* a_{jk} & \text{when} \quad \mu_{i-1} < k < \mu_i \quad \text{for} \quad i = 1, \ldots, \nu \\ c_k^* & \text{when} \quad k > \mu_\nu \end{cases}$$

The optimization problem takes then the following form:

$$\sum_{k=1}^{n} d_k^E y_k^E - \sum_{k=1}^{n} d_k^I y_k^I = S$$

$$\sum_{j=\mu_{i-1}+1}^{\mu_i} a_{kj} x_j + y_k^I - y_k^E = P_k \quad \text{for} \quad \mu_{i-1} < k \leq \mu_i \quad (i = 1, \ldots, \nu)$$

$$x_k + y_k^I - y_k^E = P_k \quad \text{for} \quad k > \mu_\nu$$

$$0 \leq x \leq b_k \; ; \quad 0 \leq y_k^E \leq \pi_k^E \; ; \quad 0 \leq y_k^I \leq \pi_k^I \; ;$$

---

[1] Conceptually we put into operation the economy so as to produce a unit of commodity $k$ : $\sum_{j=1}^{n} a_{ij} x_j^+ = \delta_{ki}$ , using the Cramer formula we can determine the volume of production $x_j^+$ for particular $j$ , necessary to produce a unit of $k$ : $x_j^+ = \frac{1}{|a|} (-1)^{k+j} A_{kj}$ ; $c_k^* = \sum_{j=1}^{n} c_j x_j^+$ ; hence $c_j^* = (-1)^k \frac{1}{|a|} \sum_{j=1}^{n} (-1)^j c_j A_{kj}$ .

$$\sum_{k=\mu_{\nu}+1} c_k^* x_k + \sum_{i=1}^{\nu} \sum_{k=\mu_{i-1}+1}^{\mu_i} x_k \sum_{j=\mu_{i-1}+1}^{\mu_i} c_j^* a_{jk} = \text{minimum}$$

Eliminating the balance of trade equation by introducing the marginal rate M as a parameter into the preference function--leads to the formulation of separate optimization problems for each group of interrelated activities. Hence we arrived at the first profit maximizing criterion introduced as an obligatory criterion for decision-making in planning and management:

$$\sum_{k=\mu_{i-1}+1}^{\mu_i} [M(d_k^E y_k^E - d_k^I y_k^I) - (c_k^* y_k^E - c_k^* y_k^I)] = \text{maximum}$$

This criterion has been first called: "maximization of social savings" criterion. Its main task was to enable a rational decentralization of decision-making in foreign trade planning and management.

The next step consisted in merging the model of optimization of the volume and commodity structure with the model of optimization of geographical allocation of foreign trade. It has been demonstrated, that the model of geographical allocation is an integral part of the over-all model of optimization of the volume, commodity structure and geographical allocation of foreign trade.[1] In practice these models formed a sufficient basis for the formulation of pragmatic rules and instructions for optimizing procedures.

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[1] W. Trzeciakowski; Problemy Kompleksowego Systemu Analizy Biezacej Efektywndsci Handlu Zagranicznegd (Problems of a System of Complex Analysis of Current Effectiveness of Foreign Trade) in Studia Kpzk Pan Tom II, Warsaw, 1961.

The introduction of the profit concept based on "complete labor costs" considerations has been theoretically much more compatible with the criteria used hitherto. Moreover the concept of "complete labor cost" of a commodity could be based on existing accounting data (though with huge practical difficulties), as for any other concept (e.g. price, relying on scarcity rents) there existed no statistical information basis whatsoever. However, from the conceptual point of view it was felt that the use of "complete labor outlays" relying on the simplifying assumptions applied to class b--has not been a theoretically satisfactory solution. The conceptual breakthrough came, when the decomposition methods, formulated by Kantorovich and Dantzig-Wolfe became known.

At that time the decomposition approach has been conceptually reformulated.[1]

## 6.4. The General Model of Short-Run Optimization of the Volume, Commodity Structure and Geographical Allocation of Foreign Trade

The general assumptions of the initial model are identical to the former. The starting point is the necessity to satisfy final demand, for consumption and investment, established in the central plan of development, while minimizing social outlays of labor . The levels of production and foreign trade are the variables, while final demands and the required balance of trade with particular markets are the given constants. Production capacity

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[1] J. Mycielski, K. Rey, W. Trzeciakowski: "Decomposition and Optimization of Short-Run Planning in a Planned Economy," in Structural Interdependences in Economic Development, edited by T. Barna, Macmillan, London, 1963.

in the short run is assumed to be fixed. The former solution was based on the simplifying assumptions that commodities belonging to the group of inter-related activities under consideration are not raw materials for the rest of the economy; and that raw materials used in such a group and originating from outside of this group are produced domestically and do not limit the outputs based on them. These simplifying assumptions were now rejected. Besides the restrictive commodity approach has been replaced by the more general concept of activity, which allows for the use of different techniques in the production of a commodity, as well as for the existence of by-products. Hence the number of activities and constraints in the model is now larger than the number of commodities.

The following notation is used:

$x_j$ - the level of production activity $j$ (in physical units)

$a_{kj}$ - the output (with positive sign) or input (with negative sign) of commodity $k$ per unit of activity $j$

$y_k^{Er}$ - exports of commodity $k$ to market $r$ (in physical units)

$y_k^{Ir}$ - imports of commodity $k$ from market $r$ (in physical units)

$P_k$ - domestic demand for commodity $k$ for consumption and investment

$d_k^{Er}$ - export price of a unit of commodity $k$ in foreign currency on the market $r$ (f.o.b. frontier)

$d_k^{Ir}$ - import price of a unit of commodity $k$ in foreign currency from market $r$ (c.i.f. frontier)

$S^r$ - the planned balance of trade with market $r$

$b_j$ - maximum capacity of activity $j$ (in physical units)

$\pi_k^{Er}$ - demand on market r for the export of commodity k of the given country

$\pi_k^{Ir}$ - supply on the market r of the commodity k imported by the country

$c_j$ - domestic processing costs (labor costs) per unit of activity j in the last phase of processing (costs of raw materials and depreciation omitted)

p - the number of productive activities

m - the number of foreign markets

n - the number of commodities

The condition of satisfying final demands for each consumption and investment good is:

$$\sum_{j=1}^{p} a_{kj}x_j + \sum_{r=1}^{m} y_k^{Ir} - \sum_{r=1}^{m} y_k^{Er} = P_k \qquad (k = 1, \ldots, n) \tag{1}$$

The condition of balancing trade in each foreign market r is:

$$\sum_{k=1}^{n} d_k^{Er} y_k^{Er} - \sum_{k=1}^{n} d_k^{Ir} y_k^{Ir} = S^r \qquad (r = 1, \ldots, m) \tag{2}$$

The boundary conditions are:

-- that production is kept within the limits of

$$0 \leq x_j \leq b_j \qquad (j = 1, \ldots, p) \tag{3}$$

-- that exports of commodity k to the market r cannot exceed the demand for this commodity in that market:

$$0 \leq y_k^{Er} \leq \pi_k^{Er} \qquad (k = 1, \ldots, n;\ r = 1, \ldots, m) \tag{4}$$

-- that imports of commodity k from market r cannot exceed the supply of this commodity in that market:

$$0 \leq y_k^{Ir} \leq \pi_k^{Ir} \qquad (k = 1, \ldots, n;\ r = 1, \ldots, m) \tag{5}$$

The optimization criterion consists of minimizing aggregate domestic costs:

$$\sum_{j=1}^{p} c_j x_j = \text{minimum.}$$

Because of the huge number of commodities and possible techniques of production, the problem is practically untractable in this form. Two different ways of approach are possible.

The aggregation approach consists in reducing the number of equations and variables by aggregating commodities and activities. This however makes the model practically useless for short-run planning, since the concepts of production constraints, material inputs, unit costs of production, foreign prices, demand and supply, concern specific goods and not aggregate groups of commodities. Moreover, aggregation involves processing with a fixed structure within particular groups. This necessarily reduces drastically the number of degrees of freedom. It is obvious that a loss in the number of degrees of freedom involves losses in capacity utilization.

In order to avoid this deficiency we adopt the second possible approach--that of decomposition. The economy can be decomposed into its parts or even into particular enterprises. Then inserting some parameters, having the dimension of exchange rates ($M^r$) and shadow prices ($\ell_k$) the optimization problems for these parts can be formulated and the method of obtaining the

values of the parameters can be given. In this way an over-all optimum can be achieved through solving partial optimization problems. These partial problems do not, as a rule, exceed the possibilities of computational techniques, and, in general, they are even so simple that optimization can be based on intuitive methods of profit maximization, using simple indicators of effectiveness. The necessity for a widespread reporting system can also be avoided since this approach permits substantial decentralization of planning procedures.

The central parameters, which coordinate partial and overall optima, have substantial stability in their dependence on detailed parameters of calculation, such that the price, demand and supply of a given commodity on a given market. This leads to the possibility of frequent adjustments of separate parts of the foreign trade plan which take into account for instance changing terms of trade, without changing the whole plan or its central parameters, which--as experience shows--may be relatively seldom corrected.

The decomposition theorem applied by J. Mycielski and K. Rey to the optimization problem (1)-(6), and based on the works of Kantorovich and of Dantzig-Wolfe is described in the Annexe to this chapter. On the basis of the decomposition theorem described in the Annexe it is possible to formulate the partial optimization problem.[1] The initial optimization problem (1)-(6) is of the form (22)-(24). We drop the foreign trade balance equations and make the appropriate change in the expression (6). Choosing some subset of productive activities $x_j$ (e.g. $j = 1, \ldots, \alpha$), commodities (e.g.

[1] See: J. Mycielski, K. Rey and W. Trzeciakowski: "Decomposition..." op.cit.

$k = 1, \ldots, \beta)$, and trade $y_k^{Er}$ and $y_k^{Ir}$ $(k = 1, \ldots, \beta\ ;\ r = 1, \ldots, m)$ we can write the problem of the form (37)-(39) in the appendix but now for maximization:

$$\sum_{j=1}^{\alpha} a_{kj}x_j + \sum_{r=1}^{m} y_k^{Ir} - \sum_{r=1}^{m} y_k^{Er} = P_k - \sum_{j=\alpha+1}^{p} a_{kj}x_j^0 \quad (k = 1, \ldots, \beta) \tag{40}$$

$$0 \le x_j \le b_k \quad (j = 1, \ldots, \alpha) \tag{41}$$

$$\left.\begin{aligned} 0 \le y_k^{Er} \le \pi_k^{Er} \\ 0 \le y_k^{Ir} \le \pi_k^{Ir} \end{aligned}\right\} \quad (k = 1, \ldots, \beta;\ r = 1, \ldots, m) \tag{42, 43}$$

$$\sum_{r=1}^{m} M^r \sum_{k=1}^{\beta} (d_k^{Er}y_k^{Er} - d_k^{Ir}y_k^{Ir}) - \sum_{j=1}^{\alpha} (c_j - \sum_{k=\beta+1}^{p} l_k a_{kj})x_j = \max \ . \tag{44}$$

where $x_j^o$ = activities in the rest of the economy.

The procedure described in the Annexe for obtaining the optimal solution for the problem (22)-(24) can now be used here--at least in theory--to obtain the optimal solution (1)-(6). We start from some arbitrary[1] solution of (1)-(5): $x_j^o$ $(j = 1, \ldots, p)$, $y_k^{Ero}$ and $y_k^{Iro}$ $(r = 1, \ldots, m;\ k = 1, \ldots, n)$. We choose also the values of commodity shadow prices $l_k$ $(k = 1, \ldots, n)$ and marginal rates of foreign markets $M^r$ $(r = 1, \ldots, m)$. Taking different subsets of activities and commodities, we solve by any standard procedure the problems of the form (40)-(44), obtain new $x_j$'s, $y_k^{Er}$'s, $y_k^{Ir}$'s and $l_k$'s for activities and commodities from these subsets, use them in the

[1] Experience has shown, that in practice only feasible (and not unfeasible) solutions could be applied. Unfortunately this approach does not guarantee that each iterative step be feasible and monotonic in the improvement of the preference function.

next problems and thus go through the whole economy. $M^r$'s must be changed during this procedure in order to obtain the fulfillment of equations (2). We stop when the iterations do not give any more changes in $x_j$'s, $y_k^{Er}$'s, $y_k^{Ir}$'s, $\ell_k$'s and $M^r$'s. The optimal solution of (1)-(6) is then reached.

For practical planning it is of course extremely important to have the least possible number of iterations. For this reason it is essential that the starting values of parameters be as close as possible to the optimum position. Such a solution which is certainly feasible and does not worsen the existing solution is that based on statistical or plannistic data. It is important to exploit the following properties of the optimal solution:

$$\ell_k \begin{cases} \geq M^r d_k^{Er} & \text{if } y_k^{Er} = 0 \\ = M^r d_k^{Er} & \text{if } 0 < y_k^{Er} < \pi_k^{Er} \\ \leq M^r d_k^{Er} & \text{if } y_k^{Er} = \pi_k^{Er} \end{cases} \tag{45}$$

$$\ell_k \begin{cases} \geq M^r d_k^{Ir} & \text{if } y_k^{Ir} = \pi_k^{Ir} \\ = M^r d_k^{Ir} & \text{if } 0 < y_k^{Ir} < \pi_k^{Ir} \\ \leq M^r d_k^{Ir} & \text{if } y_k^{Ir} = 0 \end{cases} \tag{46}$$

In the global optimal solution a system of shadow prices $\ell_k$ is available, which makes it possible to judge whether each small post of the phase taken separately is correct. The existence of such a system is a sufficient condition for the plan to reach its optimum. Thus these prices--if known--can become an instrument for optimizing a plan. Then prices contain full processing costs, corresponding to all phases of production and corrected by allowances for scarcity and for potential foreign trade possibilities.

Knowing: 1) the value of shadow prices $\ell_k$ for basic raw materials coming from outside the group taken under consideration.

2) the values of shadow prices of separate foreign currencies $M^r$, which determines how many units of domestic currency one is ready to pay for a unit of foreign currency--one can find the optimum for a given group, optimizing at the same time the overall solution.

## 6.5. The Implications of the Model Analysis for the Practical Improvement of Planning and Management

The non-numerical analysis of the models presented above and of the properties of their optimal solutions leads to several important conclusions.

The probably most important conclusion is that it fully confirms the statements made earlier by O. Lange[1] that economic calculus and rational pricing are not only needed but also possible in planned economies. This means, that effectiveness considerations are not incompatible with the preferences of the central planner. On the contrary, if rationally determined, they reinforce the sphere of active operation of the planner's preferences. The methods of direct commands, used hitherto exclusively in planning may be replaced or complemented--if and where necessary--by a method of indirect management, operating with prices and the profit criterion, without endangering the central planners' preferences. This means that the conclusions of the

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[1] Lippincott, B. (ed.): On the Economic Theory of Socialism, Minneapolis, 1938.

model analysis can be used in practice.

First--the effectiveness criteria derived from the model analysis can be used as a general check of planning proposals submitted by the executive levels.

Second--the use of central parameters and the formulation of profit criterion--enable the decentralization of the complex and multi-level procedure of planning. This approach makes it possible to take advantage of a potentially much higher number of alternative choices analyzed at executive levels in the course of planning processes in a way consistent with the overall preferences. The set of marginal rates $M^r$ becomes thus an elastic instrument of the central planner for shaping the balance of trade in strict connection with the shapping of the commodity structure and directions of foreign trade. Increasing $M^r$ has a positive influence on the balance of trade and vise versa. Needless to say how important it is for the release of all potential reserves of initiative at the level of individual enterprises, which possess a much more detailed knowledge of prices and constraints on individual markets.

Third--there is a possibility of connecting the profit criterion based on shadow prices with incentive systems, using thus stimuli in full accordance with the overall preferences. Relying on the properties of the optimal solution --shadow prices can be determined and catalogues of shadow prices permit the application of profits as a source of premiums.

Fourth--there is a possibility to change the strictly passive character of rates of exchange and prices into active instruments of rational decision making in planning and management. Assuming that the marginal rates $M^r$

can be computed and knowing the foreign currency prices of basic raw materials --it is possible to determine rational prices of materials for producers, using these prices as a powerful instrument of efficient allocation of resources.

The analysis of the properties of the optimal solution allows thus the formulation of prescriptive techniques, which can transform the existing pattern of decision-making. The discussion of how this transformed pattern of planning and management has been implemented in practice is to be found in Part III.

## APPENDIX TO CHAPTER 6

### The Decomposition Theorem[1]

Kantorovich's problem of optimization is the following. Suppose we have the real numbers

$$A_{is} \quad (i = 1, \ldots, N;\ s = 1, \ldots, \nu)\ , \tag{7}$$

$$B_i \quad (i = 1, \ldots, \mu) \tag{8}$$

$$K_j > 0 \quad (j = 1, \ldots, N-\mu)\ , \tag{9}$$

$$D_s > 0 \quad (s = 1, \ldots, \nu)\ . \tag{10}$$

The variables $z_s$ $(s = 1, \ldots, \nu)$ fulfil the conditions

$$D_s \geq z_s \geq 0 \quad (s = 1, \ldots, \nu)\ , \tag{11}$$

$$\sum_{s=1}^{\nu} A_{is} z_s \geq B_i \quad (i = 1, \ldots, \mu)\ . \tag{12}$$

We intend to find the variables $z_s$ in such a way as to give the maximal value to the expression

$$\min_{1 \leq j \leq N-\mu} \left( \frac{1}{K_j} \sum_{s=1}^{\nu} A_{\mu+js} z_s \right)\ . \tag{13}$$

Such set of $z_s$'s is called the optimal plan.

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[1] J. Mycielski, K. Rey, W. Treciakowski: "Optimum Calosciowe a Optima Czastkowe w Planowaniu Handlu Zagranicznego" (Over-all and Partial Optima in Foreign Trade Planning) in Przeglad Statystyczny Nr. 1, 1963, Warszawa.

Kantorovich's theorem states that the necessary and sufficient condition for optimality of the plan $z_s$ which fulfils the conditions (11) and (12), is the existence of the Lagrange multipliers ('shadow prices') $\ell_i$ $(i = 1, \ldots, N)$ fulfilling the following conditions

$$\text{(a)} \quad \ell_i \geq 0 \quad (i = 1, \ldots, N) , \quad \max_{1 \leq j \leq N-\mu} \ell_{\mu+j} > 0 ,$$

$$\text{(b)} \quad \sum_{i=1}^{N} \ell_i A_{is} \begin{cases} \leq 0 & \text{if } z_s = 0 , \\ = 0 & \text{if } D_s > z_s > 0 , \\ \geq 0 & \text{if } z_s = D_s , \end{cases} \quad (s = 1, \ldots, \nu) ,$$

$$\text{(c)} \quad \ell_i = 0 \quad \text{if} \quad \sum_{s=1}^{\nu} A_{is} z_s > B_i \quad (1 \leq i \leq \mu) , \quad \text{or}$$

$$\sum_{s=1}^{\nu} A_{is} z_s > K_{i-\mu} \min_{1 \leq j \leq N-\mu} \left( \frac{1}{K_j} \sum_{s=1}^{\nu} A_{\mu+js} z_s \right) \qquad (\mu+1 \leq i \leq N) .$$

Let us now specify Kantorovich's theorem in the case

$$N = \mu+1 \tag{14}$$

and denote $A_{\mu+1s}$ by $-C_s$ . Then Kantorovich's problem reduces to

$$0 \leq z_j \leq D_j \quad (j = 1, \ldots, \nu) , \tag{15}$$

$$\sum_{j=1}^{\nu} A_{kj} z_j \geq B_k \quad (k = 1, \ldots, \mu) , \tag{16}$$

$$\sum_{j=1}^{\nu} C_j z_j = \min . \tag{17}$$

From part (a) of Kantorovich's theorem we have

$$\ell_{\mu+1} > 0 . \tag{18}$$

We can put $\ell_{\mu+1} = 1$ and conclude that the necessary and sufficient condition for optimality of the plan $z_s$, which fulfils the conditions (15) and (16), is the existence of $\ell_k$ $(k = 1, \ldots, \mu)$ fulfilling the conditions

$$\ell_k \geq 0 \qquad (k = 1, \ldots, \mu), \tag{19}$$

$$\sum_{k=1}^{\mu} \ell_k A_{kj} \begin{cases} \leq C_j & \text{if } z_j = 0, \\ = C_j & \text{if } 0 < z_j < D_j, \\ \geq C_j & \text{if } z_j = D_j, \end{cases} \quad (j = 1, \ldots, \nu), \tag{20}$$

$$\ell_k = 0 \quad \text{if} \quad \sum_{j=1}^{\nu} A_{kj} z_j > B_k \qquad (1 \leq k \leq \mu). \tag{21}$$

Now we investigate the problem

$$\sum_{j=1}^{\nu} A_{kj} z_j = B_k \qquad (k = 1, \ldots, u;\ u < \nu), \tag{22}$$

$$0 \leq z_j \leq D_j \qquad (j = 1, \ldots, \nu), \tag{23}$$

$$\sum_{j=1}^{\nu} C_j z_j = \min. \tag{24}$$

The equalities (22) can be written

$$\left.\begin{aligned} \sum_{j=1}^{\nu} A_{kj} z_j &\geq B_k, \\ \sum_{j=1}^{\nu} (-A_{kj}) z_j &\geq -B_k. \end{aligned}\right\} \quad (k = 1, \ldots, u) \tag{25}$$

The problem (22)-(24) is then of the type (15)-(17).

We use the theorem (19)-(21), inserting $\ell_k'$ and $\ell_k''$ respectively for the first and second type of the inequalities (25) and denoting $\ell_k = \ell_k' - \ell_k''$. We then conclude that the necessary and sufficient condition for optimality of the plan $z_s$ which satisfies the conditions (22) and (23), is the existence of $\ell_k$ $(k = 1, \ldots, u)$ satisfying the conditions (20). In this way we arrive at the well-known theorem for the shadow prices.

Applying this theorem, we can formulate the method of obtaining the optimal solution of the problem (22)-(24). We choose a set of numbers $\ell_k$ $(k = 1, \ldots, u)$ and take the values of $z_j$ $(j = 1, \ldots, v)$ in accordance with the conditions (20). If such a solution does not satisfy the conditions (22), we have to repeat the procedure with another set of $\ell_k$'s, until (22) will be satisfied. In the given step of iteration the inequality $\sum_{j=1}^{v} A_{kj} z_j > B_k$ suggest that $\ell_k$ must be lowered, the opposite one suggests that is much be raised.

This method, although simple in principle, is not convenient because of the great number of iterations which are required for larger problems. This difficulty arises from the great number of $\ell_k$'s (equal $u$) which have to be chosen and then changed. Because of that, we shall write the theorem in a different form which is more elastic in practical application. For this purpose let us consider the following problem:

$$\sum_{j=1}^{v} A_{kj} z_j = B_k \qquad (k = 1, \ldots, k'-1, k'+1, \ldots, u), \tag{26}$$

$$0 \leq z_j \leq D_j \qquad (j = 1, \ldots, v), \tag{27}$$

$$\sum_{j=1}^{v} C_j z_j - \ell_{k'} \sum_{j=1}^{v} A_{k'j} z_j = \min . \tag{28}$$

We shall prove that, first, if $\ell_{k'}$ is the shadow price of the problem (22)-(24), then the optimal solution of the problem (22)-(24) is the optimal solution also for the problem (26)-(28); the shadow prices of the problem (22)-(24) are the shadow prices also for the problem (26)-(28). Second, if the optimal solution of the problem (26)-(28), with some number $\ell_{k'}$, satisfies the condition

$$\sum_{j=1}^{\nu} A_{k'j} z_j = B_{k'} , \tag{29}$$

then it is also the optimal solution of the problem (22)-(24); the shadow prices of the problem (26)-(28) and the number $\ell_{k'}$ give the complete set of shadow prices for the problem (22)-(24).

We shall now prove the first part of the theorem. The optimal solution of (22)-(24) is of course a feasible solution of (26)-(28), i.e. it satisfies the conditions (26) and (27). The sufficient condition for this solution for being also the optimal solution of (26)-(28) is the existence of such $\ell'_k$ ($k = 1, \ldots, k'-1, k'+1, \ldots, u$) that:

$$\sum_{\substack{k=1 \\ k\neq k'}}^{u} \ell'_k A_{kj} \begin{cases} \leq C_j - \ell_{k'} A_{k'j} & \text{if } z_j = 0 , \\ = C_j - \ell_{k'} A_{k'j} & \text{if } 0 < z_j < D_j , \\ \geq C_j - \ell_{k'} A_{k'j} & \text{if } z_j = D_j . \end{cases} \quad (j = 1, \ldots, \nu) . \tag{30}$$

Such $\ell'_k$ exist: they are by definition the shadow prices of the problem (22)-(24).

We now treat the second part of our theorem. The optimal solution of (26)-(28), satisfying (29), is the feasible solution of (22)-(24). The sufficient

condition for this solution for being also the optimal solution of (22)-(24) is the existence of such $\ell_k'$ $(k = 1, \ldots, \mu)$ that:

$$\sum_{k=1}^{\mu} \ell_k' A_{kj} \begin{cases} \leq C_j & \text{if } z_j = 0 , \\ = C_j & \text{if } 0 < z_j < D_j , \\ \geq C_j & \text{if } z_j = D_j . \end{cases} \quad (j = 1, \ldots, \nu) . \tag{31}$$

If we put

$$\ell_{k'}' = \ell_{k'} , \tag{32}$$

we see that such $\ell_k'$'s $(k = 1, \ldots, k'-1, k'+1, \ldots, \mu)$ exist: they are, by definition, the shadow prices for the problem (26)-(28). (Compare conditions (30).) This completes the proof of our theorem.

The theorem proved can easily be generalized, simply by iteration, for the case in which not only one but several conditions (22) are omitted, i.e. for the problem:

$$\sum_{j=1} A_{kj} z_j = B_k \quad (k = 1, \ldots, k_1-1, k_1+1, \ldots, k_\sigma-1, k_\sigma+1, \ldots, \mu), \ \sigma \leq \mu , \tag{33}$$

$$0 \leq z_j \leq D_j \qquad (j = 1, \ldots, \nu) , \tag{34}$$

$$\sum_{j=1}^{\nu} C_j z_j - \sum_{j=1}^{\sigma} \ell_{ki} \sum_{j=1}^{\nu} A_{kij} z_j = \min . \tag{35}$$

If $\ell_{ki}$ $(i = 1, \ldots, \sigma)$ are the shadow prices of the problem (22)-(24), then the optimal solution of this problem is the optimal solution also for the problem (33)-(35); the shadow prices of the problem (22)-(24) are the shadow prices also for the problem (33)-(35). On the other hand, if the optimal solution of the problem (33)-(35), with some numbers $\ell_{ki}$ $(i = 1, \ldots, \sigma)$, satisfy the conditions

$$\sum_{j=1}^{\nu} A_{kij} z_j = B_{ki} \qquad (i = 1, \ldots, \sigma) , \tag{36}$$

then it is also the optimal solution of the problem (22)-(24); the shadow prices of the problem (33)-(35), and the numbers $\ell_{ki}$ $(i = 1, \ldots, \sigma)$ give the complete set of shadow prices for the problem (22)-(24).

On the basis of this theorem we can solve the problem (22)-(24) in the following way. We can drop some of the equations (22) which are most inconvenient, e.g. because they tie together several subsets of $z_j$'s, these subsets being otherwise independent on each other. The problem takes then the form (33)-(35). We choose the values of $\ell_{ki}$ $(i = 1, \ldots, \sigma)$ and solve the problem by any standard method. If the solution does not satisfy the conditions (36) we must repeat the procedure of solving (33)-(35) with another set of $\ell_{ki}$'s, until (36) will be satisfied. On the given step of iteration the inequality $\sum_{j=1}^{\nu} A_{kij} z_j > B_{ki}$ suggest that $\ell_{ki}$ must be lowered, and the opposite one that it must be raised. The shadow prices and $\ell_{ki}$ $(i = 1, \ldots, \sigma)$ obtained in the last step of iteration are the right shadow prices for the problem (22)-(24).

Let us consider now the problem (33)-(35) in which some of the unknown $z_{j_t}$ (for $t = 1, \ldots, \theta$; $\nu - \theta > \mu - \sigma$) were fixed on their optimal values $z^0_{j_t}$. The problem is:

$$\sum_{\substack{j=1 \\ j \neq j_t (t=1,\ldots,\theta)}}^{\nu} A_{kj} z_j = B_k - \sum_{t=1}^{\theta} A_{kjt} z_{jt} \quad (k = 1, \ldots, k_1-1, k_1+1, \ldots, k_\sigma-1, k_\sigma+1, \ldots, \mu) , \tag{37}$$

$$0 \leq z_j \leq D_j \qquad (j = 1, \ldots, \nu;\ j \neq j_t \text{ for } t = 1, \ldots, \theta), \tag{38}$$

$$\sum_{\substack{j=1 \\ j\neq j_t (t=1,\ldots,\theta)}}^{\nu} C_j z_j - \sum_{j=1}^{\sigma} \ell_{ki} \sum_{\substack{j=1 \\ j\neq j_t (t=1,\ldots,\theta)}}^{\nu} A_{kij} z_j = \min. \qquad (39)$$

It is obvious that the optimal solution of $z_j$ ($j \neq j_t$ for $t = 1, \ldots, \theta$) of the problem (33)-(35) is the optimal solution also for this problem, and that the shadow prices for the problem (33)-(35) are also the shadow prices for (37)-(39). This leads to some possible modification of our method of obtaining the optimal solution of the problem (22)-(24). We start from some feasible or even unfeasible solution of (22)-(23), and treat these $z_j$'s ($j = 1, \ldots, \nu$) for the moment as $z_j^0$. We choose also the values of $\ell_k$'s ($k = 1, \ldots, \mu$). Taking then an arbitrary subset of equations and a subset of $z_j$, we find by any standard procedure the solution of the problem (37)-(39). We obtain then a new set of values $z_j^0$ ($j \neq j_t$, $t = 1, \ldots, \theta$) and shadow prices $\ell_k$ ($k \neq k_i$, $i = 1, \ldots, \sigma$). We now go to another subset of equations and unknowns and repeat the procedure. We can thus go through the whole problem and stop when the iterations do not give any more changes in $z_j^0$'s and $\ell_k$'s. These will be the optimal solution and shadow prices. Some of the equations must not be taken into account in any problem of type (37)-(39) but their $\ell_k$'s must be then changed during the iteration procedure so as to obtain the fulfilment of these equations.

## 7. THE MODEL OF OPTIMIZATION OF FAST RECOUPERATING INVESTMENTS [1]

### 7.1. FORMULATION

The mathematical formulation of the model of optimization of fast recouperating investments, the problem of the adequate measure of the investment funds and of capital inputs, the decomposition of planning fast recouperating investments, the simplest cases of investment problems, the problem of the optimal repartition of the total investment fund will be discussed in successive sub-chapters.

Fast recouperating investments are defined as such investments for which the construction period is short and the duration period long as compared with the "recoupment period" of the capital input while this "recoupment period" is short.

Thus, basing on the priciple of maximizing the results when the level of inputs is given, we can formulate the problem of optimization of fast recouperating investments, as a problem of minimizing current costs in the following period e.g., during the next year/ under condition of fulfilling the planned targets for this period/such as consumer and investment demands, foreign currency balances etc.,/ and of maintaining the investment funds established for fast recouperating investments for the basic period. Remaining investments are treated as given.

We introduce the following notation:

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[1] by J. Mycielski and W. Trzeciakowski, Foreign Trade Research Center, Warszawa, 1966. (Printed as manuscript.)

$x_j$ / $j = 1,\ldots, n$ / - the level /in the following period/ of the production /or service/ activity $j$ / the "production decision variable"/ connected with production capacities <u>independent</u> of fast recouperating investment invested during the present period.

$x'_j$ / $j = 1,\ldots, p$ / - the level /in the following period/ of production /or service/ activity $j$ /the "production decision variable"/ connected with the production capacities <u>dependent</u> on fast recouperating investment invested during the present period.

$a_{kj}$ / $k = 1,\ldots, m$ ; $j = 1,\ldots, n$ / - the amount of commodity /or service/ $k$ produced per unit of production /or service/ activity $x_j$ /when input of commodity $k$ then $a_{kj} < 0$/.

$a'_{kj}$ / $k = 1,\ldots, m$ ; $j = 1,\ldots p$ / - the amount of commodity /or service/ $k$ produced per unit of production /or service/ activity $x'_j$ /when input then $a'_{kj} < 0$/.

$y_k^{Er}$, $y_k^{Ir}$ / $k = 1,\ldots, m$ ; $r = 1,\ldots,s$/ - exports and imports, respectively of commodity /service/ $k$ from market $r$ /"foreign trade decision variables"/.

$v_l$ - investment decision variables, connected with fast recouperating investment realized /or which can be realized/ during the present period.

$d_k^{Er}$, $d_k^{Ir}$ / $k = 1,\ldots, m$ ; $r = 1,\ldots, s$/ - export and import prices /respectively fob or cif of a unit of commodity /or service/ $k$ on market $r$, expressed in currency of market $r$, in the next period.

$\pi_k^{Er}$, $\pi_k^{Ir}$ /k = 1, ..., m ; r = 1, ..., s/ - demand and supply on market r for „our" exports and imports of commodity /service/ k in the next period.

$P_k$ /k = 1, ..., m/ - domestic consumer and investment demand for commodity /service/ k in the next period.

$S^r$ /r = 1, ..., s/ - the balance of foreign trade with market r, planned for the next period.

The set of all production decision variables $x_j$ will be divided into separate subsets /groups/ $X_i$ ; each such subset of decision variables corresponds to a certain production capacity independent of fast recouperating investments realized in the present period. In a similar way, the set of all production decision variables $x'_j$ and investment decision variables $v_l$ will be divided into separate subsets $X'_h$ ; in each such subset there is at least one variables $x'_j$ and one variable $v_l$ .

Each subset $X'_h$ corresponds to some production capacity dependent on fast recouperating investments, realized during the present period. The subsets $X'_h$ will be connected into separate groups $R_t$ - each such group includes the subsets $X'_h$ corresponding to the production capacities dependent on fast recouperating investments of the administrative sector t of the economy. It should be noted, that if the investments of the same type - from the technical point of view--can be made independently by two or more administrative sectors, then such investments will be treated as different from the formal point of view /i.e. a separate subset $X'_h$ is

assigned to each of them/. This however is only true of "new" investments, i.e. such investments which do not consist in modifying old capital equipment. In the case of investments which improve such equipment, it is assumed that they belong to one sector only.

Furthermore, we introduce the following notation:

$F_t$ - the investment fund of sector $t$ concerning fast recouperating investments for the present period

$I_l$ - capital input per unit of investment decision variable $v_l$ /in the present period/.

The problem of the adequate measure of $F_t$ and $I_l$ will be discussed in the next chapter.

Let us now set up our optimization problem. The conditions of fulfilling the balances of consumer and investment commodities and services, the currency balances on foreign markets, and the supply and demand restrictions on those markets in the next period can be written as follows:

$$\sum_{j=1}^{n} a_{kj} x_j + \sum_{j=1}^{p} a'_{kj} x'_j + \sum_{r=1}^{s} y_k^{Ir} - \sum_{r=1}^{s} y_k^{Er} = P_k ; \qquad /1/$$

$$/k = 1, \ldots, n/$$

$$\sum_{k=1}^{n} d_k^{Er} y_k^{Er} - \sum_{k=1}^{n} d_k^{Ir} y_k^{Ir} = S^r ; \qquad /2/$$

$$/r = 1, \ldots, s/$$

$$0 \leq y_k^{Er} \leq \pi_k^{Er} \qquad /3/$$

$$/k = 1, \ldots, m;\ r = 1, \ldots, s/$$

$$0 \leq y_k^{Ir} \leq \pi_k^{Ir} \qquad /4/$$

The conditions resulting from technology and from the size of production capacities independent of fast recouperating investments realized in the present period may be written in a general way as:

> For each $i$ : inequalities for the separate $x_j \in X_i$ /especially $x_j \geq 0$ for each $x_j \in X_i$/ as well as homogeneous or non-homogeneous linear equations containing only $x_j \in X_i$ . /5/

The conditions resulting from the technology of production capacities depending on fast recouperating investments realized in the present period, from the size of actually existing plants /if they are to be modified/, or resulting from limitations due e.g., to natural conditions, limited availability of the qualified labour and appropriate equipment, decisions of state authorities protecting the national economy from the risks of extreme specialization in production etc., can be written in a general way as:

> For each $h$ : inequalities for separate $x'_j \in X'_h$ and $v_l \in X'_h$ /especially $x'_j \geq 0$ for each $x'_j \in X'_h$ and $v_l \geq 0$ for each $v_l \in X'_h$ / as well as homogenous or nonhomogenous linear equations containing only $x'_j \in X'_h$ and $v_l \in X'_h$ . /6/

It should be noticed that increasing the value of investment decision variables may sometimes lead to limiting certain production or service activities, as e.g. in the case of modifying production capacities when we cancel certain technologies in favour of some others.

The conditions of allocating all investment funds devoted for fast recouperating investments in separate sectors for the present period are:

$$\sum_{\substack{l \\ v_l \in R_t}} I_l v_l = F_t \qquad \text{/for all } t\text{/} . \qquad \text{/7/}$$

Our problem of optimization of fast recouperating investments consists in minimizing current costs in the next period, fulfilling the conditions /1/ - /7/, that is to say in minimizing the expression:

$$\sum_{j=1}^{n} c_j x_j + \sum_{j=1}^{p} c'_j x'_j = \text{minimum}, \qquad \text{/8/}$$

in which the following notation was used:

$c_j$ /j = 1, ..., n/ - direct labour cost /in the next period/ connected with establishing the production decision variable $x_j$ on a unit level;

$c'_j$ /j = 1, ..., p/ - direct labour cost /in the next period/ connected with establishing the production decision variable $x'_j$ on a unit level.

## 7.2. THE PROBLEM OF THE CORRECT MEASURE OF THE INVESTMENT FUNDS AND OF CAPITAL INPUTS

It will be demonstrated, that capital inputs $I_1$ in the present period per unit of the investment decision variable $v_1$ /and, therefore, also the investment funds $F_t$ of separate sectors in the present period/ should be measured in direct costs of labour plus material inputs priced at shadow prices /"efficiency prices" or "calculation prices"/ $l_k^o$ of the investment commodities /or services/ in the present period.

Let us take the optimal solution of problem /1/ - /8/ . Now, let us somewhat change some of the values of the variables $v_1$ , belonging to a certain $R_t$ in such a way, that there is still a solution fulfilling the condition /1/ - /6/ and that the change of capital inputs resulting from the change of $v_1$-s , priced according to the direct labour costs and $l_k^o$ , is equal to zero. Since $l_k^o$ is equal to the marginal costs of commodity /or service/ k , the change of the value of $v_1$-s does not lead to a change of the social labour cost in the present period on fast recouperating investments. Thus, if we minimize expression /8/ for the changed values of the $v_1$-s adjusting the values of $x_j$ and $x_j'$ , and keeping the conditions /1/ - /6/, then we should not obtain the value of /8/ smaller than in the initial solution, if this initial solution actually realizes our principle of maximizing the effects when the level of outlays is given.

As a matter of fact, if the proportions of the $I_1$-s in the equation of investment outlays of sector t correspond to the proportions of calculation costs of inputs per unit of investment variable /measured in direct

labour costs and $l_k^o$ /, then it is impossible to reach in the modified solution a lower value of /8/, than the one in the initial solution. This results from the fact, that the modified solution is a feasible solution of problem /1/ - /8/ / the balance of investment outlays of sector t is kept/. On the other hand, however, if the proportions of the $I_l'$-s in the equation of investment outlays of sector t do not correspond to the proportions of the calculation costs of inputs per unit of investment variable /measured in direct labour costs and $l_k^o$ /, then the modified solution may not be a feasible solution for problem /1/ - /8/, since the balance of the investment outlays of sector t may not be fulfilled /e.g., it may be overfulfilled/. Thus it may happen that the modified solution gives a smaller value of /8/, than the initial solution.

## 7.3. PLANNING OF FAST RECOUPERATING INVESTMENTS

Now we will apply the principle of partial decomposition for linear optimization problems, presented in the former chapter to the problem of optimization of fast recouperating investments. It follows from the above principle, that if we omit the conditions /1/, /2/ and /7/ in problem /1/ - /8/ substracting their left-hand sides, multiplied by shadow prices corresponding to those conditions, from the minimized expression /8/, then the problem of optimization modified in such a way has an optimal solution identical with t he optimal solution of problem /1/ - /8/. If the shadow prices, corresponding to the conditions /1/, /2/ and /7/ are unknown, then taking initially arbitrary figures, we adjust them in such a way which assures that the optimal solution of the modified optimization problem fulfills the conditions /1/, /2/ and /7/. This solution is then the optimal

solution of problem /1/ - /8/ and the figures thus determined are the shadow prices of conditions /1/, /2/ and /7/ for this problem.

Let us now draw attention to the fact that the conditions appearing in the modified optimization problem can be divided into groups, each one of which is related to another group of decision variables. Thus, each one of the conditions /3/ and /4/ is related to another foreign trade decision variables, each group of conditions /5/ is related to another group of $x'_j$-s , and each group of conditions /6/ is related to another group of $x'_j$-s and $v_l$-s . The minimized expression in the modified optimization problem may also be divided into parts, each one of which depends only on decision variables belonging to one group. Thus, we can optimize the modified problem, optimizing independently separate groups of decision variables. Each such optimization subproblem consists in minimizing this part of the minimized expression in the modified problem which depends on the variables belonging to a given group, while the group of conditions corresponding to those variables is kept in mind.

The subproblem, pertaining to the trade variables or the $x_j$-s shall not be considered here, since they are similar to the ones connected with current optimization of the economy. The subproblem of optimization for the group of $x'_j$-s and $v_l$-s forming the subset $X'_h \in R_t$ consists in maximizing the expression /changing the sign of the minimized expression we change minimization into maximization/:

$$\sum_{\substack{j \\ x'_j \in X'_h}} \Big/ \sum_{k=1}^{m} l_k a'_{kj} - c'_j \Big/ x'_j - \alpha_t \cdot \sum_{\substack{l \\ v_l \in X'_h}} I_l v_l = \text{maximum}, \qquad /9/$$

keeping this set of conditions amongst the sets /6/, which is related to the $X'_h$ under consideration. $l_k$ stands in expression /9/ for the shadow price /"efficiency price"/ of commodity/or service/ k; the shadow prices of foreign currences /"marginal exchange rates"/ do not appear in expression /9/. The figure $\alpha_t$ is the shadow price of fast recouperating investment inputs of sector t , taken with an opposite sign and it has the dimension of the rate of interest. It will be called the efficiency rate of interest /of investment inputs of sector t on fast recouperating investments/. Thus the maximized expression /9/ has a simple economic meaning: it is the "profit" on production minus tne rate of interest on investment inputs.

Now, the iterations procedure of planning consists in choosing certain values for efficiency prices, marginal exchange rates, and efficiency rates of interest, in solving all optimization problems for $X'_h$ , $X_i$ , $y_k^{Er}$ and $y_k^{Ir}$ , and in checking whether the economic plan thus obtained fulfills the balance equations for commodities /services/ /1/, foreign currencies /2/ and investment inputs /7/. If the balance equations are not fulfilled, then the procedure must be repeated, changing the values of prices, exchange rates, and rates of interest, until all the balance equations will be fulfilled. Thus we obtain the optimal solution and adequate values of efficiency prices, marginal exchange rates, and efficiency rates of interest. If in some iteration step a certain balance of commodities /services/, foreign currency or investment is overfulfilled, this suggests that the corresponding value of the price or exchange rate should be decreased and

that of the rate of interest--increased /5-6/. The inverse is true if a certain balance was too low.

Once we have adequate efficiency prices of commodities /services/ $l_k$, the optimization of fast recouperating investments for a certain sector $t$ consists in adjusting the value of one shadow price only, namely, of the rate of interest $\alpha_t$. This should be done in such a way, as to assure that the investment plan of sector $t$ consisting of optimal solutions for the separate $X'_h \in R_t$ fulfills the balance of investment inputs of this sector.

It should be noticed, that if the values of the decision variables $v_l$ are established on optimal levels, then the problem of optimization /1/ - /8/ changes into a problem of current optimization in the following period. This, however, does not change the shadow prices corresponding to the balance equations of commodities /services/ or those of foreign currencies. Thus, the adequate efficiency prices of commodities /services/ $l_k$ for problem /1/ - /8/, appearing in expression /9/ are also the adequate efficiency prices for the problem of current optimization in the following period.

Let us observe that all the above considerations are valid also in the case in which some of the variables $v_l$ are the decision variables determining the dismantlement of the old production capacities. The coefficients $I_l$ corresponding to those variables $v_l$ should be measured in cost of labour of dismantlement minus the material output priced according to $l^o_k$. Therefore, those coefficients will be, in general, negative.

## 7.4. THE SIMPLEST CASES OF INVESTMENT PROBLEMS

One of the simplest investment problems is concerned with establishing by a given sector /administrative unit/ a new production capacity /the size of which will be denoted as $v$ / used for producing by way of a certain technology, one commodity /or service/ or one set of commodities or services. The level of production in the following period will be denoted by $x'$, which of course can not exceed the size of the production capacity $v$ which has been invested. In other words, the idle part of the production capacity $x'_+$ can not be negative. In turn, the size of $v$ is limited, e.g. by natural conditions, by the amount of qualified labour necessary to build a given plant etc. The highest possible value of $v$ will be denoted as $B$.

The subset $X'_h$ under consideration has three elements: it contains the decision variables $x'$, $x'_+$ and $v$. The problem of optimizing those variables consists, according to /9/, in maximizing the following expression /idle capacities do not lead to production or outlays of commodities /services/ or to labour costs/:

$$/ \sum_{k=1}^{m} l_k a'_k - c'/x' - \alpha Iv = \text{maximum} \qquad /10/$$

under the following conditions:

$$x' + x'_+ = v , \qquad /11/$$

$$x' \geq 0 , \qquad /12/$$

$$x'_+ \geq 0 , \qquad /13/$$

$$B \geq v \geq 0 . \qquad /14/$$

In formula /10/ the subscripts j, l, t, were not used owing to the fact, that a definite group of decision variables belonging to a definite sector was considered.

Let us assume that $\alpha > 0$ . Taking /11/ into account expression /10/ can be written as:

$$/ \sum_{k=1}^{m} l_k a'_k - c' - \alpha I / x' - \alpha I x'_+ = \text{maximum} \qquad /15/$$

If having $x'$ determined at a certain level we will diminish the value of $x'_+$ /and also the value of $v$, so that /11/ will always be fulfilled/, then expression /15/ will increase. Thus in the optimal solution

$$x'_+ = 0 \qquad /16/$$

and basing on /11/

$$x' = v \, . \qquad /17/$$

The relations /16/ and /17/ have a simple economic meaning: the new production capacity should be fully employed. Those relations enable to reduce our optimization problem /10/ - /14/ to a problem with only one unknown which is the investment decision variable $v$ :

$$B \geq v \geq 0 \, , \qquad /18/$$

$$/ \sum_{k=1}^{m} l_k a'_k - c' - \alpha I / v = \text{maximum} \, . \qquad /19/$$

Here the optimal solution depends on the sign of the expression in brackets in formula /19/ or, in other words, on the value of the quotient of "profit"

over investment inputs, that is to say

$$\left/ \sum_{k=1}^{m} l_k a'_k - c' \right/ : I \text{ , namely:}$$

$$\text{when } \frac{\sum_{k=1}^{m} l_k a'_k - c'}{I} \begin{matrix} < \\ = \\ > \end{matrix} \alpha \quad \text{then} \quad \begin{matrix} v = 0 \text{ ,} \\ 0 \leq v \leq B \text{ ,} \\ v = B \text{ .} \end{matrix} \qquad /20/$$

The solution /20/ has also a simple economic meaning.

Let us now consider another simple investment problem. Let us assume that we have a certain production capacity /the size of which will be denoted as B/, used for producing, by way of a certain technology, one definite commodity /or service/, or one definite set of commodities /services/. The level of production by that technology in the following period will be denoted as $x'_1$ and the idle part of that technology as $x'_2$ . Let us further assume that it is possible to modify within the sectoral limits of the fast recouperating investment fund, the whole or a part of this production capacity in such a way that it may produce--using a new technology--the same commodity as previously, or another /but only one, definite/ commodity /service/ or set of commodities /services/. The level of production using this new technology in the following period will be denoted as $x'_3$ and the idle part of the production capacity, using this new technology--as $x'_4$ . The investment decision variables will be determined as the size of this part of the production capacity considered, which was subject to modification; it will be denoted by v.

The subset $X'_h$ considered has five elements, it contains the decision variables $x'_1$ , $x'_2$ , $x'_3$ , $x'_4$ and v . We write the conditions of type /6/, related to those variables. The balance of the unmodified part

of the production capacity is:

$$x'_1 + x'_2 = B - v \qquad /21/$$

and the balance of the modified part of that capacity is:

$$x'_3 + x'_4 = v \, . \qquad /22/$$

It is obvious, that the following conditions must be also fulfilled:

$$x'_1 \geq 0 \, , \qquad /23/$$

$$x'_2 \geq 0 \, , \qquad /24/$$

$$x'_3 \geq 0 \, , \qquad /25/$$

$$x'_4 \geq 0 \, , \qquad /26/$$

$$B \geq v \geq 0 \, . \qquad /27/$$

The problem of optimizing the group of decision variables considered, consists, according to /9/, in maximizing the following expression under conditions /21/ - /27/ /idle capacities do not lead to production or to outlays of commodities/ services /or labour costs/:

$$\Big/ \sum_{k=1}^{m} l_k a'_{k1} - c'_1 \Big/ x'_1 + \Big/ \sum_{k=1}^{m} l_k a'_{k3} - c'_3 \Big/ x'_3 - \alpha \, Iv = \text{maximum.} \qquad /28/$$

The subscripts 1 and t were not used in /28/, since we were considering a given group of decision variables, belonging to a given administrative sector.

When the expression in the first brackets in /28/ is positive, then we obtain an increase in expression /28/ when increasing $x_1'$ /and changing $x_2'$ according to condition /21//. The opposite is true, when the expression in the first bracket in /28/ is negative. This leads to the conclusion, that in the optimal solution:

when $$\sum_{k=1}^{m} l_k a'_{kl} - c'_1 \begin{matrix} > \\ = \\ < \end{matrix} 0$$

then
$$\begin{cases} x_1' = B - v , \quad x_2' = 0 ; \\ 0 \leq x_1' \leq B - v , \quad x_2' = B - v - x_1' ; \\ x_1' = 0 , \quad x_2' = B - v . \end{cases} \qquad /29/$$

Thus, in the following period, production based on the old technology will be continued, if it is bringing "profits" /and if $v \neq B$, i.e. if not all production capacity will be subject to change/.

Let us assume, that $\alpha > 0$. Reducing the value of $x_4'$ to zero and reducing the value of $v$ in such a way as to assure the fulfillment of condition /22/ we obtain an increase of expression /28/. Thus, in the optimal solution:

$$x_3' = v , \qquad /30/$$

$$x_4' = 0 . \qquad /31/$$

The economic meaning of /30/ and /31/ is very simple: if we decide to modity a part /or the whole/ of the production capacity considered, then this modified part will be fully employed.

Substituting /29/ and /30/ in /28/, and omitting the expression

$$B \max \quad / 0, \sum_{k=1}^{m} l_k a'_{kl} - c'_1 /$$

as constant, we may transform our optimization problem into a problem with only one unknown $v$, that is to say into the problem of maximizing--under condition /27/--the expression:

$$\left[ \sum_{k=1}^{m} l_k a'_{k3} - c'_3 - \max / 0, \sum_{k=1}^{m} l_k a'_{kl} - c'_1 / - \alpha I \right] v = \text{maximum}, \qquad /32/$$

Here the optimal solution depends on the sign of the expression in square brackets in /32/, or--in other words--on the value of the quotient of "profit" achieved basing on the new technology diminished by the "profit" on production based on the old technology /this substraction--diminishment--takes place only when this "profit" is positive/, over the investment inputs:

$$\text{when} \qquad \frac{\sum_{k=1}^{m} l_k a'_{k3} - c'_3 - \max / 0, \sum_{k=1}^{m} l_k a'_{kl} - c'_1 /}{I} \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} \alpha \qquad /33/$$

$$\text{then} \qquad \begin{cases} v = 0 , \\ 0 \leq v \leq B , \\ v = B . \end{cases}$$

The solution /33/ has a simple economic meaning.

It should be noted, that if for a certain administrative sector $t$, all $X'_h \in R_t$ are of the type discussed in this chapter, then having the proper values of $l_k$ but not knowing the value of $\alpha$, we can easily find it and optimize all fast recouperating investments of this sector. To achieve this aim, it is enough to range all proposed investments according to the value of the index--using the index in /20/ or in /33/, depending on the kind of proposed investment--and include them successively into the plan /taking $v = B$/ --beginning with the highest values of the index and going down towards the lower ones. Thus the whole investment fund of the sector considered will be used. The index of the last investment included in the plan is equal to the efficiency rate of interest $\alpha$ of this sector. Generally speaking, for this last investment we already have: $0 < v < B$, owing to the necessity of fulfilling the equations of investment inputs of the sector.

Let us now go back to the first investment problem considered in the present chapter. We shall investigate a special case of that problem: we assume that the new production capacity produces some commodity /e.g., $k = 1$/ which can be exported to the market $r$ /$1 \leq r \leq s$/, and that the possibilities of export of the commodity $k = 1$ to the market $r$ are not completely utilized--in other words, that the demand for export of commodity $k = 1$ on the market $r$ is higher than the actual export. We shall express the level of the production activity under consideration by the production of the commodity $k = 1$; thus $a'_1 = 1$.

As we already know, in the case of the investment problem under consideration we should invest if the expression in brackets in /19/ is positive, i.e., if:

$$l_1 > c' + / - \sum_{k=2}^{m} l_k a'_k / + \alpha I \ . \qquad /34/$$

The expression in brackets in /34/ is the material input--priced at efficiency prices--per unit of the commodity $k = 1$ /minus possible by--production priced also at efficiency prices/.

The marginal exchange rate of the currency of the market $r$ --i.e., the shadow price of the corresponding equation /2/--will be denoted by $M^r = K^r M^\circ$; $K^r$ is here the ratio of the marginal exchange rate of the market $r$ to the marginal exchange rate $M^\circ$ of a certain market taken as basic one.

It is well-known /see Chapter 6 / that if the possibilities of export of the commodity $k = 1$ to the market $r$ are not completely utilized--as we assumed--then:

$$l_1 \geq M^r d_1^{Er} = M K^r d_1^{Er} \ . \qquad /35/$$

It follows from /35/ that the sufficient /but not necessary! / condition for /34/ --i.e., for investment to be profitable /in our case of investment problem/--is:

$$M K^r d_1^{Er} > c' + / - \sum_{k=2}^{m} l_k a'_k / + \alpha I \ . \qquad /36/$$

Let us denote:

$$WEI = \frac{c' + / - \sum_{k=2}^{m} l_k a'_k / + \alpha I}{K^r d_1^{Er}} \qquad /37/$$

The condition /36/ can be written now in the form:

$$WEI < M^{\circ}. \qquad /38/$$

The above consideration can be done-with the same result--also in the case when there exists import of the commodity $k = 1$ from the market $r$. One has only to replace $d_1^{Er}$ by $d_1^{Ir}$ and to use the well-known fact /see Chapter 6 / that if there exists import of the commodity $k = 1$ from the market $r$ then :

$$l_1 \geq M^r d_1^{Ir} = \dot{M}K^r d_1^{Ir} . \qquad /39/$$

## 7.5. PROBLEM OF THE PROPER DIVISION OF THE TOTAL INVESTMENT FUND

Let us consider the problem of the optimal division of the total investment fund destined for fast reouperating investments amongst the administrative sectors. It will be demonstrated, that when the total fund is divided in the proper way the efficiency interest rates $\alpha_t$ are the same in all sectors. If the interest rate $\alpha_t$ of some sector is higher than in others, this shows, that the investment fund $F_t$ of this sector should be increased at the cost of others. The opposite is true, when $\alpha_t$ of some sector is lower than in others.

Let us assume, that the efficiency interest rate $\alpha_{t_1}$ of sector $t_1$ is higher than the rate $\alpha_{t_2}$ of sector $t_2$:

$$\alpha_{t_1} > \alpha_{t_2} \quad . \qquad /40/$$

Now, let us increase the investment fund $F_{t_1}$ of sector $t_1$ by a certain small amount $\Delta F_{t_1}$ at the cost of diminishing by the same amount, the fund of sector $t_2$:

$$\Delta F_{t_1} = - \Delta F_{t_2} > 0 \qquad /41/$$

If the capital inputs per unit of investment decision variable /and also investment funds/ are measured in units of direct costs of labour plus material inputs priced at $l_k^o$, and it was demonstrated previously that such a method is correct, then owing to the fact, that $l_k^o$ and the marginal cost of commodity /service/ $k$ are equal, the change of investment funds according to /41/ does not lead to a change of social current outlays of labour for fast recouperating investments. On the other hand, considering problem /1/ - /8/ and treating equations /7/ as balance equations for certain "commodities," we conclude that the shadow price of investment inputs of sector $t$ /that is - $\alpha_t$/ is equal to the "marginal cost" of those inputs, defined as the increase of the minimum outlays of social labour in the following period per unit increase of the investment fund of sector $t$. Thus, taking into account /40/ and /41/, the increase of the minimum outlays of social labour in the following period, due to the changes of investment funds of sectors $t_1$ and $t_2$ under consideration is:

$$/-\alpha_{t_1}/\Delta F_{t_1} + /-\alpha_{t_2}/\Delta F_{t_2} = /\alpha_{t_2} - \alpha_{t_1}/\Delta F_{t_1} < 0 \; . \qquad /42/$$

Thus, the changes of investment funds considered lead to a decrease of the minimum outlay of social labour in the following period, without changing the outlay of labour on fast recouperating investments in the present period. Thus, according to our principle of maximizing the effects, when outlays are given, those changes are advantageous.

If the total investment fund for fast recouperating investments is divided in the optimal way among the administrative sectors, this means, that there is no possibility of making any advantageous shifts of this fund among sectors. It follows that the efficiency rates of interest $\alpha_t$ of all sectors must be equal.

# 8. THE FINANCIAL SYSTEM AND EFFECTIVENESS IN MANAGEMENT. [1]

## 8.1. INTRODUCTION.

The purpose of this chapter is to show how the financial system can be used to manage the planned economy. We are interested here only in the theory of optimal management /optimal planning/.

Of course, the planned economy can be managed by direct orders of the central planning authority, without using the financial tools. An example of this method of management is offered by the procedure of two-level optimal planning, proposed by Kornai and Liptak [2] . However, the number of direct tasks given by the central planning authority must be enormous /being equal to the product of the number of commodities by the number of enterprises in the Kornai-Liptak procedure/. This makes the method of management by direct orders unmanageable in practice, at least if optimal planning of the whole national economy is concerned.

Another method of optimization of the planned economy described in chapter 6 was proposed by J. Mycielski, based on the decomposition methods for linear programs of Kantorovich and Dantzig and Wolfe. It consists in maximizing, by each enterprise /i.e. subset of production and trade activities/, the shadow price based profit /"accounting profit"/ and in changing

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[1] Based on the paper by J. Mycielski and W. Trzeciakowski, prepared for the II World Congress of Econometric Society, Cambridge, September 1970 (Printed as Manuscript).

[2] Janos Kornai and Thomas Liptak, "Two-Level Planning," Econometrica, Vol. 33, 1965, pp. 141-169.

the shadow prices by the central planning authority in such a way as to fulfill the balances of all the commodities. The number of parameters which must be chosen--and then changed--by the central planning authority in this procedure, is still very high /equals the number of commodities/ but much smaller than in the direct orders method. Therefore, the "profit maximization method" of optimal planning seems to be more suitable in practice and has been already used on a large scale in planning the geographic and commodity structure of the Polish foreign trade.

It should be mentioned that the profit maximization method is appropriate, in principle, only in the field of short-term planning /"currency optimization"/. Therefore, the financial system we are interested in can not be expected to be useful for the long-term planning purposes.

Although the principle of the profit maximization method does not depend on which balance was chosen as the objective function, the dimensions of the shadow prices depend on this choice. In the following, we shall assume that the total labour cost /corresponding to the production and service activities/ is the objective function of the macro-model to be minimized, and that the shadow prices are expressed, consequently, in the domestic currency (as described in Chapter 6).

It is obvious that the profit maximization method of planning can be used without any links with the financial system /except for the system of wages used to measure the labour cost/. An example of such situation is offered by the planning of foreign trade in Poland, where the "accounting profit" has been connected with an incentive system. The functions of the

financial system--to keep the accumulation on the proper level, to maintain the equilibrium on the market of the consumer goods etc.--are performed then by the financial system's prices, financial exchange rates and financial profits, while for the planning purposes the shadow prices, marginal exchange rates /i.e. shadow prices of the foreign currencies/ and accounting profits are used.

It is worthwhile, however, to see for the possibility of integrating both systems--the financial system and the system of short-run planning--for this may simplify the management significantly. Moreover, this should cancel the possible contradictions between the planning and financial systems and facilitate the functioning of incentives connected with the planning system. The purpose of this paper is to construct such an integrated financial and planning system; in other words, to construct the financial system which may be used for the short-run optimal planning decisions in accordance with the profit maximization principle.

We begin with some comments on the relation between the shadow prices and retail prices /Section 2/. Then, in Section 3, we construct the financial objective function and the financial system's prices, exchange rates, taxes and subsidies; optimal planning in an enterprise consists in maximizing this objective function. In Section 4, three variants of the financial system are discussed. Some additional remarks on the taxes and subsidies are made in Section 5.

## 8.2. SHADOW PRICES AND RETAIL PRICES.

It is well-known that the shadow prices have the economic meaning of

the marginal costs of the commodities /services/. In other words, the shadow price of a given commodity is equal to the increase of the total labour cost in the economy, caused by the unit increase of the balance of this commodity. The values of the shadow prices depend on labour costs involved in processing, on technological coefficients, foreign export and import prices, production capacities, demands and supplies on t he foreign markets, and on the planned structure and volume of the final product of the national economy. The same factors determine the total labour cost in the national economy, corresponding to the production and service activities. The shadow price of the commodity $k$ will be denoted in the following by $l_k$ ; if the commodity is the currency of the foreign market $r$ , the shadow price of it /i.e. the marginal exchange rate/ will be denoted by $M^r$ .

We denote the retail price [1] of the commodity /service/ $k$ on the domestic market of the consumer goods by $W_k$ , and the planned volume of the individual consumption of this commodity by $P_k^C$ /the use of the commodity $k$ for investment and collective consumption is not included in $P_k^C$/. $L^i$ denotes the labour cost in the enterprise $i$ , and $B$ is the difference between that part of the wage-fund which does not correspond to the production and service activities /pensions, pay in the army, wage of the administration etc./ and that part of the consumers' income which is not spent on the individual consumption /savings, some taxes, etc./. The condition of the overall equilibrium on the market of the consumer goods can be written

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[1] For the sake of simplicity, we shall disregard the difference between retail and wholesale prices of consumer goods.

now as:

/1/ $$\sum_k W_k P_k^C = \sum_i L^i + B \ .$$

The retail prices $W_k$ have to assure not only the overall equilibrium /1/ , but also the equality of the supply of /i.e. $P_k^C$/ and the demand for each commodity /service/ on the market of the consumer goods. It follows that--for given collective consumption--the proper values of the retail prices depend on $\sum_i L^i + B,\ P_k^C$

and on the preferences of the consumers /and also on the form of the dependence of $B$ on $P_k^C$, if such dependence exists/.

Let us now denote by $\beta$ the relative level of the shadow prices, as compared with the retail prices. More precisely, $\beta$ is defined as the ratio of the individual consumption **bundle prices according to shadow prices to the same bundle** priced according to retail prices:

/2/ $$\beta = \frac{\sum_k l_k P_k^C}{\sum_k W_k P_k^C}$$

Using /1/, $\beta$ can be written in the form:

/3/ $$\beta = \frac{\sum_k l_k P_k^C}{\sum_i L^i + B} \ .$$

One can now observe that $\beta$ depends on $B$, $P_k^C$ and on these factors which determine the shadow prices and the total labour cost corresponding to the production and service activities. In other words, $\beta$ depends only on $B$ and the parameters of the problem of current optimization of the national economy. It does not depend on the preferences of the consumers /although the structure of the system of retail prices--at given $P_k^C$ --depends on these preferences/.

It should be mentioned that there is no reason for $\beta$ to be equal to unity in the planned economy [1/] . The rate of accumulation /for investment and collective consumption/ is a decision variable of the central planning authority, and $\beta$ depends on that rate. A higher rate of accumulation means lower values of $P_k^C$ at given $\sum_i L^i$ , and thus higher values of $W_k$ and lower $\beta$ . If the difference between the marginal and the average costs of producing consumer goods is small, it is necessary--for keeping the accumulation on the required level--to maintain the level of retail prices not only above the average costs but also above the marginal costs of producing these goods, at least if $B$ is not large and negative; thus in this case $\beta < 1$ . If, however, the difference between the marginal and the average costs is large, the level of retail prices corresponding to the appropriate volume of accumulation may be located below the marginal costs, at least if $B$ is not large and positive; therefore, in that case $\beta > 1$ . If, however, the difference between the marginal and the average costs is large, the level

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[1/] In the perfect free-market economy--with perfect competition and in absence of any taxes or subsidies, except for income tax--there is $W_k = l_k$ and, therefore, $\beta = 1$ .

of retail prices corresponding to the appropriate volume of accumulation may be located below the marginal costs, at least if $B$ is not large and positive; therefore, in that case $\beta > 1$.

We have assumed already that $W_k$ are the equilibrium prices at the planned values of $P_k^C$; therefore, $W_k$ depends on the preferences of the consumers. It does not mean, however, that the structure of the individual consumption /i.e. of the system of $P_k^C$ / is determined according to the consumers' preferences, Assuming this additionally, i.e. assuming that the planned values of $P_k^C$ maximize the consumers' utility function at given $\Sigma_i L^i$, investment and collective consumption, we can derive /for $B$ independent of $P_k^C$ / --as it is well-known--the principle of the mutual proportionality of the shadow prices and the equilibrium retail prices [1]. In that principle, the coefficient of the proportionality equals, of course, $\beta$; i.e. for all consumer goods /commodities and services/

/4/ $$l_k = \beta W_k \quad .$$

Using /4/, for a given value of $\beta$, one can determine the values of $P_k^C$ and the corresponding values of $W_k$ and $l_k$. For this purpose one has to know $l_k$ and $W_k$ as the functions of $P_k^C$ /for given $k$, the prices $l_k$ and $W_k$ depend on all $P_k^C$/. The first of these functions

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[1] Jerzy Mycielski, "Ceny kalkulacyjne, ceny detaliczne, kursy dewizowe," Gospodarka Planowa, No. 12, 1965, pp. 24-33. This paper deals also with the relationship between $\beta$ and the marginal exchange rate, on the one hand, and some exchange rates derived from the retail prices /as the "maximal exchange rate," defined by Kalecki and Polaczek/, on the other hand.

can be derived on the basis of the current optimization problem of the national economy, and the second from the price elasticities of the demands for consumer goods and from $\sum_i L^i + B$ as the function of $P_k^C$ /this function is determined by $B$ and again by the problem of optimization of the economy/.

It should be noted that the principle /4/, even if accepted, should not be used without exceptions. For this could result, for instance, in determining the retail price of liquor at too low a level from the point of view of the public interest /even though it might be consistent with the consumers' preferences/, and in determining the prices of books at too high a level.

## 8.3. THE PRINCIPLES OF THE PROPOSED FINANCIAL SYSTEM.

We shall try now to construct the financial system which may be used for the optimal decision-making in the short-run according to the profit maximization principle.

First of all, we shall postulate that in the financial system there exists only one system of prices $V_k$ and exchange rates $N^r$ in the sphere of production, i.e. paid to and by the producers /admitting the possibility of a different retail price system $W_k$ /. It is not necessary, of course, for the financial system to be based on only one system of prices and exchange rates in the sphere of production, and the actual financial systems of the planned economies are often based on several price and exchange rates systems in that sphere. It seems, however, that the financial system based on only one system of prices $V_k$ and exchange rates $N^r$ will be simpler and more effective in operation, providing it is possible to design it so as to fulfill the requirements of economic policy /e.g. the financial equilibrium, the appropriate volume of accumulation etc./ which are sometimes

regarded as arguments in favour of a differentiated system of prices and exchange rates. As we shall show in the following, it is possible to design the financial system in this way.

If the financial system has to be the basis for the current optimization of the national economy according to the concept of profit maximization, we must postulate the equivalence of the accounting profit and the financial objective function to be maximized in each enterprise. The equivalence of these two objective functions means that the second of them is an increasing function of the first. Since it is most convenient to take--as the objective function in the financial system--a linear function of inputs and outputs of commodities, and to express it in the domestic currency, we conclude that the financial objective function should be equal to the accounting profit multiplied by a certain positive dimensionless constant $a^i$, minus a certain constant $Q^i$. Of course, it is possible to form from this "basic" objective function of the financial system other objective functions /as, e.g., the financial incentives fund/ by taking some non-linear, increasing functions of the "basic" function. It should be stressed also that the constants $a^i$ and $Q^i$ may be different for different enterprises.

We shall denote by $p_k^i$ the difference between output and input of the commodity /service/ $k$ in the enterprise $i$. In other words, $|p_k^i|$ is the net output of the commodity $k$ in the case $p_k^i > 0$, and the net input of this commodity in the case $p_k^i < 0$

The "basic" financial objective function of the enterprise $i$ can be written now in the form:

/5/ $$a^i \Big/ \sum_k l_k p_k^i - L^i \Big/ - Q^i \ .$$

It should be noted that if the enterprise $i$ is exporting to or importing from the foreign market $r$ then one of the $p_k^i$ denotes the foreign currency receipts or expenditures, and the corresponding $l_k$ should be understood as the marginal exchange rate $M^r$ .

Now we must write the financial objective function /5/ using not the shadow prices $l_k$ and marginal exchange rates $M^r$ , but the prices $V_k$ and exchange rates $N^r$ of the financial system /in the sphere of production/. The outputs and inputs of the particular commodities are priced in /5/ proportionally to $l_k$ /or $M^r$ /, It seems unavoidable--from the point of view of the simplicity of the financial system--to postulate that these outputs and inputs should be priced proportionally to $V_k$ /or $N^r$ /, if /5/ is written using the financial system's prices. Therefore, we have to postulate the mutual proportionality of the system of shadow prices and marginal exchange rates and the system of prices $V_k$ and exchange rates $N^r$ :

/6/ $$V_k = b\, l_k$$

for all commodities, and

/7/ $$N^r = b\, M^r$$

for all foreign markets. The positive constant $b$ must be dimensionless if the financial system's prices are expressed in domestic currency, and it must be independent of $i$ , for otherwise, there would exist more than one system of prices $V_k$ and exchange rates $N^r$ in the sphere of production

/contrary to our postulate/.

The financial objective function /5/ can be written now as

$$/8/ \qquad \frac{a^i}{b} \sum_k V_k p_k^i - a^i L^i - Q^i \quad .$$

If the enterprise $i$ is exporting to or importing from the foreign market $r$ then one of the $p_k^i$ denotes the foreign receipts or expenditures, and the corresponding $V_k$ should be understood as the exchange rate $N^r$.

Let us denote by $Z^{Gi}$ the gross financial profit of the enterprise $i$, i.e. the difference between the value of outputs prices according to the price system $V_k$ and the value of inputs priced according to the same price system, and the direct labour cost:

$$/9/ \qquad Z^{Gi} = \sum_k V_k p_k^i - L^i \quad .$$

We shall define also the taxes $T^{Ai}$ and $T^{Li}$ as

$$/10/ \qquad T^{Ai} = / i - \frac{a^i}{b} / \sum_k V_k p_k^i \quad ,$$

$$/11/ \qquad T^{Li} = / a^i - 1 / L^i \quad .$$

Now we can write the "basic" financial objective function /8/ of the enterprise $i$ in the form of the net financial profit $Z^{Ni}$ :

$$/12/ \qquad Z^{Ni} = Z^{Gi} - T^{Ai} - T^{Li} - Q^i \quad .$$

Economic decisions concerning current management should be made at particular enterprises according to the principle of maximization of $Z^{Ni}$. The central planning authority has to change the prices $V_k$ and exchange rates $N^r$ in such a way as to assure the fulfillment of the balances of all commodities and of the foreign trade with all foreign markets. Of course, only a part of $Z^{Ni}$ should be left at the disposal of the enterprise /e.g. in the form of the financial incentives fund/; the main part of $Z^{Ni}$ should be transferred to the State budget in the form of an income tax /progressive, differentiated for various enterprises/.

Let us make some comments on the taxes $T^{Ai}$ and $T^{Li}$. First of all, if $a^i > b$ than $-T^{Ai}$ is a subsidy; if $a^i < 1$, $-T^{Li}$ is a subsidy. One can observe also that the tax $T^{Ai}$ is proportional to the value added; $T^{Li}$ is proportional to the labour cost. Of course, both taxes are of a price-forming nature: they influence the equilibrium values of $V_k$ and $N^r$.

It follows from /12/ that $Q^i$ has also the economic meaning of a tax or charge /$-Q^i$ has the meaning of a subsidy if $Q^i$ is negative/. $Q^i$ does not depend, however, on the decision variables of current management; it may depend on, e.g., investment decision variables.

Let us note now that apart from the taxes $T^{Ai}$ and $T^{Li}$, operating in the sphere of production of commodities and services, there must usually appear in the proposed financial system one more kind of tax. This results from the fact that the retail prices $W_k$ may differ, as it was already mentioned, from the prices $V_k$ paid to the producers. The difference is a tax

operating in the sphere of individual consumption, for commodity $k$, this tax $T_k^C$ equals

$$T_k^C = (W_k - V_k)P_k^C . \tag{13}$$

If $W_k < V_k$ then $-T_k^C$ is a subsidy.

We shall denote the sum of the taxes $T_k^C$ by $T^C$:

$$T^C = \sum_k T_k^C . \tag{14}$$

Using (2), (6) and (13), we obtain

$$T^C = (1 - \beta b)\sum_k W_k P_k^C = \left(\frac{1}{\beta b} - 1\right)\sum_k V_k P_k^C . \tag{15}$$

If the principle (4) is accepted, we obtain from (6) the mutual proportionality of the system of retail prices and the system of prices in the sphere of production:

$$V_k = \beta b W_k \tag{16}$$

for all consumer goods (commodities and services). Moreover, formula (13) gives then

$$T_k^C = (1 - \beta b)W_k P_k^C = \left(\frac{1}{\beta b} - 1\right)V_k P_k^C , \tag{17}$$

i.e. the uniform rate of taxation for all consumer goods. The method of determining the values of $P_k^C$ and the corresponding values of $W_k$ and $l_k$, already briefly presented, is--because of (6) and (16)--also the method of

determining the prices $V_k$ of consumer goods and can be expressed in terms of these (and not $l_k$ ).

Let us summarize now the conclusions concerning the financial equilibrium in the proposed financial system. This equilibrium consists, first of all, in the equilibrium in the sphere of individual consumption, and is reached by maintaining the retail prices at a proper level (dependent on the required volume of accumulation) and by using the taxes $T_k^C$ . The second element of the financial equilibrium is the equilibrium of particular enterprises in the sphere of production. Also this equilibrium is ensued in the proposed financial system, at least for $Q^i \leq 0$ . This follows from the fact that in the optimal plan the accounting profit is non-negative, and the net financial profit $Z^{Ni}$ is--for $Q^i = 0$ --equal to the accounting profit multiplied by a positive constant. Thus $Z^{Ni}$ in the optimal plan is non-negative (for $Q^i \leq 0$ ).

## 8.4. VARIANTS OF THE FINANCIAL SYSTEM

In the proposed financial system with arbitrarily determined values of the constants $a^i$ and $b$ all three taxes $T^{Ai}$ , $T^{Li}$ and $T^C$ differ from zero. Moreover, it follows from (10), (11) and (15) that it is not possible, in general, to determine the values of $a^i$ and $b$ so as to assure vanishing of all these taxes; this would be possible only if $\beta = 1$ (we should take then $a^i = b = 1$ ).

It can be shown, however, that by an appropriate choice of the values of $a^i$ and $b$ it is possible, in every case, to make two of the taxes

$T^{Ai}$, $T^{Li}$ and $T^{C}$ vanish; this can be done in three ways, depending upon which tax does not vanish. We shall discuss now three thus defined variants of the proposed financial system. For practical reasons the number of the kinds of taxes in the financial system should, of course, be as small as possible; hence, the choice of the most convenient financial system is reduced to selecting one of these three variants.

Variant 1. We take $a^i = b = 1$. We have then $T^{Ai} = T^{Li} = 0$ and

$$T^{C} = (1-\beta)\sum_k W_k P_k^C = \left(\frac{1}{\beta} - 1\right)\sum_k V_k P_k^C . \tag{18}$$

The system of prices $V_k$ and exchange rates $N^r$ is identical with the system of shadow prices and marginal exchange rates, and the gross financial profit and the net financial profit (for $Q^i = 0$) are identical with the accounting profit. If the principle (4) is accepted, the retail prices $W_k$ and taxes $T_k^C$ are:

$$W_k = \frac{1}{\beta} V_k , \tag{19}$$

$$T_k^C = (1-\beta)W_k P_k^C = \left(\frac{1}{\beta} - 1\right) V_k P_k^C \tag{20}$$

for all consumer goods.

Variant 2. We take $a^i = 1$ and $b = \frac{1}{\beta}$. We have then $T^{Li} = T^{C} = 0$ and

$$T^{Ai} = (1-\beta)\sum_k V_k P_k^i . \tag{21}$$

The prices $V_k$ and exchange rates $N^r$ equal, respectively, the shadow prices and marginal exchange rates divided by $\beta$ ; the net financial profit (for $Q^i = 0$) equals the accounting profit. If the principle (4) is accepted, the retail prices $W_k$ equal the prices $V_k$ (there is only one price system in the national economy) and the taxes $T_k^C$ all vanish:

$$W_k = V_k , \tag{22}$$

$$T_k^C = 0 \tag{23}$$

for all consumer goods.

Variant 3. We take $a^i = b = \frac{1}{\beta}$ . We have then $T^{Ai} = T^C = 0$ and

$$T^{Li} = \left(\frac{1}{\beta} - 1\right) L^i . \tag{24}$$

The prices $V_k$ , exchange rates $N^r$ and net financial profit (for $Q^i = 0$) equal, respectively, the shadow prices, marginal exchange rates and accounting profit divided by $\beta$ . If the principle (4) is accepted, the retail prices $W_k$ equal the prices $V_k$ (there is only one price system in the national economy) and the taxes $T_k^C$ all vanish:

$$W_k = V_k , \tag{25}$$

$$T_k^C = 0 \tag{26}$$

for all consumer goods.

When $\beta < 1$ then, as it follows from (18), (21) and (24), $T^C$ in variant 1 , $T^{Ai}$ in variant 2 and $T^{Li}$ in variant 3 are taxes; if, however,

$\beta > 1$ then they are subsidies (with opposite sign).

It should be noted that if we take $b = \frac{1}{\beta}$, then at certain enterprises we can use variant 2 (i.e. $a^i = 1$) and at other enterprises--variant 3 (i.e. $a^i = \frac{1}{\beta}$). Of course, to the value $b = 1$ there corresponds only variant 1 (i.e. $a^i = 1$).

## 8.5. REMARKS ON TAXES AND SUBSIDIES

The taxes (subsidies) $T^{Ai}$, $T^{Li}$ and $T_k^C$ of the proposed financial system ensure not only the equilibrium, but also the current optimality of the national economy. This differentiatesthese taxes (subsidies) from such--sometimes used--taxes and subsidies (as, e.g., subsidizing export or the unprofitable productions of some commodities to fulfil the balances of the foreign trade or of those commodities) which lead to the equilibrium, but not optimality, of the economy.

It should be stressed, however, that it is sometimes necessary--from the point of view of balancing and optimization of the economy--to use some other taxes and/or subsidies than $T^{Ai}$, $T^{Li}$ and $T_k^C$. This necessity follows from the analysis of a somewhat more general model of current optimization of the economy than the one which was implicite the basis for our considerations in this work (i.e. Mycielski, Rey and Trzeciakowski)[1].

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[1] Jerzy Mycielski, Krzysktof Rey, and Witold Trzeciakowski, "Decomposition and Optimization of Short-Run Planning in a Planned Economy," Chapter 2 in T. Barna (ed.), Structural Interdependence and Economic Development, Macmillan, 1963.

Among such taxes and subsidies are custom duties and export--import subsidies resulting from the necessity of complying with the conditions of foreign trade matched sale transactions or treaties; particular imports or exports within the framework of such transactions or treaties may be, in the absence of subsidies or custom duties, "unprofitable" or too profitable."

Apart from the already discussed kinds of taxes and subsidies there exist, of course, some other fully justified taxes and subsidies which, however, result from different premises than the equilibrium and current optimization of the national economy. Here belongs the already mentioned income tax whose purpose is to prevent a major part of $Z^{Ni}$ from remaining at the disposal of the enterprise $i$, e.g. for investment purposes or in the form of the financial incentives fund. Here belong also the taxes and subsidies resulting from, e.g., the tendency to avoid risks of too narrow specialization in foreign trade, the considerations of the long-term policy of economic development (as subsidizing new, growing productions) and others.

An example of a tax justified rather by social than economic considerations is offered by the remuneration tax paid by the employees in the planned economy. The point is that in a properly constructed system of wages the labor cost of a given enterprise should include rents because of the use of certain kinds of scarce skilled labor. In other words, the wages of these groups of employees must be appropriately high. Otherwise the skilled workers will generally not be properly employed in the national economy; it will be profitable to employ them also in such enterprises in which the productivity of their labor is not sufficiently high. On the other hand, this does not mean that the employees with rare qualifications should have

the real earning equal to the "shadow price" of their labor (although their wage paid by the enterprise should equal this price). Such high earnings could be unacceptable from the point of view of the social egalitarian principle; moreover, their current influence on increasing the supply of a given kind of skilled labor on the market may be negligible, and as an incentive to increase this supply in the long run (by retraining an appropriate number of workers) they could have too strong an effect. It follows that it is necessary to levy a remuneration tax on employees, differentiated for particular groups of them. This tax should not, of course, be mistakenly regarded as the tax proportional to the wage-fund $T^{Li}$, levied on enterprises.

It should be noted here that the remuneration tax may also take a form of subsidies to remuneration paid to employees (by the Treasury, not employer). A remuneration subsidy could be used to ensure a proper standard of living for the less efficient groups of employees) e.g. those with poor qualifications, women, etc. (without giving rise to disincentives to their employment, which happens when their wages paid by the enterprises are maintained at a high level. Such a subsidy could then be an instrument of full employment policy, and can replace the lowering of the retail prices of staple consumer goods (i.e. departing from the principle)[1] in order to make possible consumption of these goods by low income groups of the population. We avoid then distortions in the consumption structure of other groups of the population, going in the direction of a relatively too high consumption of the staple consumer goods. An example of a remuneration subsidy could also be a properly determined family allowance.

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[1] Janos Kornai and Thomas Liptak, "Two-Level Planning," Econometrica, Vol. 33 (1965), pp. 141-169.

# PART III: PRACTICAL APPLICATIONS

## 9. The Transition from Models to Practical Applications

The main field of interest of Part II has been hitherto centered on the analysis of the properties of optimal solutions of particular models. Hence research has been mainly concerned with the formal, mathematical logic of reasoning, focussing the attention on the internal consistency between the accepted assumptions and the derived conclusions.

Once one leaves the restricted sphere of model analysis and one attempts to enlarge research into practical applications--the pure context of formal reasoning has to be broadened: first one has to assess the relevance of basic assumptions underlying the models to existing economic and political conditions and, second, one has the evaluate the feasibility of conclusions derived from the model analysis to reality. Formal logic of model-builders has to be complemented by value judgments of policy-makers.

### 9.1. Poland's Strategy of Development and the Need for Effectiveness

First we claim, that the elaboration of economic effectiveness criteria in planning as well as the construction of mechanisms of indirect guidance of decentralized decision-making in management as proposed in Part II both respond to the vital needs of improving the actual system of planning and management and are necessitated by the past and present evolution of the Polish economy.

In the early stages of Polish economic growth the choice of strategy was relatively simple. In the take-off period the average productivity of

labor was low, the share of the industrial sector in total output was negligible, unemployment (together with disguised unemployment in the agricultural sector) was high and there existed a structural disequilibrium between labor resources and available capital. In those curcumstances the general strategy called for accelerated industrialization and a high rate of investment. This required the creation of technical capacities for investment and an increase in social savings.

The creation of technical capacity for investment entailed dependence either on domestic production of capital equipment, or on imports. The strategy of internal and complex industrialization was selected. Limited export possibilities and general insufficiency of raw materials resulted in channelling of investments to primary sectors (mining, havy industry, etc.) which are highly capital intensive, where investment has a long gestation period and where new employment is created in the long run. On the other hand, increased social savings required the preparation of a scheme for drawing surplus labor in activity. Employment was raised by various means: by creating cheap new capacities, by increasing the number of shifts, by utilizing obsolete equipment, and by a programme of intensive education and training. All this leads to a centralistic system of planning and an inward-looking strategy of development. Also in foreign trade detailed and central decisions determined overwhelmingly the shape of foreign trade in those early stages of growth.

But with a constant development of the economy and with its growing diversification there occurred profound changes in this pattern. From the initial stage of speedy and extensive development of a highly autarkic economy

Poland went over to a more mature stage of a diversified economy with diminishing reserves of extensive factors of development. Hence the need of exploring intensive factors; this meant, first of all, a constant increase of the share of foreign trade in national income. This tendency is illustrated by Table 1.

The radical growth of foreign trade and of its share in the creation of national income was accompanied by a parallel change of the commodity structure of exports and imports. To illustrate these changes let us take statistical data of exports for 1957 and 1967 (Table 2).

Table 2 shows, that the total value of exports increased 2.5 times; while simultaneously there occurred important changes in the commodity structure, and namely the share of final industrial goods (1+2) increased 5 times and reached more than 2/3 of the total increase of exports. Export of industrial consumption goods rose more than 6 times and exceeded by 50 mln.$ the value of coal exports, while in 1957 the sole export of coal amounted to nearly 40% of export earnings.

A tendency towards a bigger share of machinery import occurred also on the import side (Table 3). The share of machinery and equipment import in total import rose from 24% to 37%, and this means, that Poland imported in 1967 over three times more machines than in 1957.

After a period of nearly 25 years of all-round industrialization and a change of the economic structure from a raw-material-agricultural structure to an industrial-agricultural structure, Poland finds itself at the threshold of a new strategy of its development which will be characterized by much greater intensity and selectivity. In this strategy, the development of a rational, international division of labor assumes a special significance.

Table 1

Dynamics of National Income and Foreign Trade
(in constant prices 1960 = 100)

| Years | National Income | Export | Import | Turnover |
|---|---|---|---|---|
| 1950 | 47 | 60 | 44 | 50 |
| 1951 | 51 | 55 | 52 | 54 |
| 1952 | 55 | 58 | 49 | 53 |
| 1953 | 60 | 65 | 50 | 57 |
| 1954 | 69 | 63 | 58 | 61 |
| 1955 | 72 | 65 | 61 | 63 |
| 1956 | 77 | 63 | 66 | 65 |
| 1957 | 86 | 61 | 79 | 71 |
| 1958 | 91 | 77 | 82 | 80 |
| 1959 | 95 | 86 | 95 | 91 |
| 1960 | 100 | 100 | 100 | 100 |
| 1961 | 108 | 114 | 114 | 114 |
| 1962 | 111 | 127 | 128 | 127 |
| 1963 | 118 | 132 | 135 | 134 |
| 1964 | 126 | 155 | 139 | 147 |
| 1965 | 135 | 169 | 161 | 164 |
| 1966 | 143 | 176 | 173 | 174 |
| 1967 | 154 | 197 | 186 | 191 |
| 1968 | 166 | 227 | 201 | 213 |
| 1969 | 169 | 245 | 223 | 239 |

Table 2

Commodity Structure of Exports, 1957 and 1967

| Commodities | 1957 | | 1967 | | Change | Dynamics 1957 = 100 |
|---|---|---|---|---|---|---|
| | mln $ | % | mln $ | % | mln $ | |
| 1. Machinery and Equipment | 195.0 | 20.0 | 911.3 | 36.1 | 716.0 | 467 |
| 2. Industrial Consumption Goods | 62.2 | 6.4 | 388.9 | 15.4 | 326.7 | 625 |
| 1 + 2 | 257.2 | 26.4 | 1300.2 | 51.5 | 1043.0 | 506 |
| 3. Raw Materials (including coal) | 594.7 | 61.0 | 833.9 | 33.0 | 239.2 | 140 |
| | 388.2 | 39.3 | 340.3 | 13.5 | -42.9 | 89 |
| 4. Agricultural Goods | 123.1 | 12.6 | 392.3 | 15.5 | 269.2 | 319 |
| Total | 975.0 | 100.0 | 2526.4 | 100.0 | 1551.4 | 259 |

Table 3

Commodity Structure of Imports, 1957 and 1967

| Commodities | 1957 | | 1967 | | Change | Dynamics 1957 = 100 |
|---|---|---|---|---|---|---|
| | mln $ | % | mln $ | % | mln $ | |
| Machinery and Equipment | 297.4 | 23.8 | 977.7 | 37.0 | +630.3 | 329 |
| Raw Materials | 664.7 | 53.1 | 1228.7 | 46.5 | +564.0 | 185 |
| Agricultural Goods | 218.0 | 17.4 | 289.1 | 10.9 | +71.1 | 133 |
| Industrial Consumption Goods | 71.4 | 5.7 | 149.1 | 5.6 | +77.7 | 209 |
| Total | 1251.5 | 100.0 | 2644.6 | 100.0 | +1393.1 | 211 |

It should be emphasized, however, that the concept of intensive and selective development of the national economy lays a special stress on increasing the effectiveness of investments, on speeding up productivity growth and the technical and organizational progress, as the principal factors of Poland's development. Intensive selective development implies the concentration of outlay and efforts on selected fields which "determine modernity of production and a rapid technical progress," which Poland, as compared with other countries, possesses relatively advantageous conditions for specialization. Therefore, selective development--implying concentration of outlay on the comparatively most effective fields in the given country--assumes in principle an intensive participation of Poland in the international division of labor, the utilization of beneficial international specialization as an element for increasing the effectiveness of economic administration and, therefore, for making it possible to achieve a higher level of economic growth and to satisfy more effectively the consumer needs of broad sections of the population. Development of this kind implies giving preferential treatment to branches specializing in exports. They should develop much faster than other branches of the national economy. Rapid growth of specialized exports should contribute to a faster overall growth of exports than the growth of industrial output and of the national income, and should create conditions for a rapid growth of imports, while maintaining equilibrium in the balance of foreign trade turnover. All this contributes to a gradual overcoming of the currently existing "foreign trade barrier," being a substantial obstacle to Poland's economic development.[1] It leads at the same time to

[1] J. Soldaczuk, Poland's Economic Relations with Countries Having Different Social Systems. "Polish Foreign Trade," no. 11/12, 1969.

the general implementation of the concept of efficiency into decision-making in overall planning and management.

## 9.2. The Evolution of the General Planning System and the Selection of the Models

The best possible theoretical proposals dealing with effectiveness systems, that would endanger the existing decision-making processes in planning would certainly be rejected as "transplants" by the policy-makers. Hence, our second claim is, that the proposed methods of efficiency analysis and of indirect guidance of decision-making at executive levels, constitute a reinforcement and rationalization of existing decision-making processes. Assuming that central parameters are determined at a proper level, methods of indirect management enlarge the sphere of influence of central preferences, thus supplementing traditional plan directives. The growth and diversification of the Polish economy excludes the possibility of maintaining the methods of constructing detailed and rigid plans. The traditional system of hierarchical planning and counter-planning has to be reinforced by horizontal coordination. This means the necessity of enlarging the system of planning in value terms instead of planning in kind, and results in the strengthening of decentralization processes in the multi-level decision-making pattern. Hence the search for intensive ways of development and the need for decentralizing an important share of planning decisions stressed the necessity to introduce the analysis of effectiveness as an obligatory tool for the selection of plan variants at executive levels.

On the basis of the classification of planning and management systems (Chapter 1) we reached the conclusion, that economic decision-making has to operate in a framework where mixed decision-making systems coexist. In principle there are no reasons why the dual approach should lead to antagonistic conflicts with the primal model. Hence the proposed indirect system of profit maximization based on shadow pricing should operate in full conformity with the system of direct planning.

On the basis of the analysis of the planning system looked upon as a multi-stage decision-making system [Chapter 2.1]--it is justified to assume that all non-linearities, non-convexities, increasing returns to scale and uncertainties are dealt with within the framework of decision-making in longer-term plans. Thus the simplifying assumptions of short-run optimization models (linearities, convexities, non-existence of increasing returns to scale and of uncertainties) are tolerable from the practical point of view.

On the basis of the analysis of the planning system looked upon as a multi-level decision-making structure (Chapter 2.2)--it has been claimed that a non-numerical analysis of the properties of the optimal solution may lead to the formulation of useful rules of behavior for planning--and management agents.

One could argue, that the selection of a different model-approach, i.e. maximization of national income instead of minimization of labor costs as a preference function--could lead to different rules[1] (e.g. shadow prices

[1] This point has been raised by Prof. Z. Czerwinski, Poznan University in his excellent comments on the choice of optimization models, JBKiC, W-wa, 1970.

of labor instead of labor costs, maximization of value added instead of maximization of profits, etc.). This is correct. However, from various possible preference functions of the central planner[1] this solution should be selected, which reflects the decision-making pattern closest to reality. From this point of view, one may claim, that the models described in Part II fulfil this condition, as

-- there is no practical way of measuring national incomes of different commodity structures in centrally planned economies; on the other hand the assumption of a stable structure of national income to be maximized seems to be too harmful.

-- the notion of profit maximization is commonly known and the shadow prices of producers goods can be determined through foreign trade prices. On the other hand the notion of value added is less measurable, as the rational pricing of final demand would prove to be more complicated, due to the lesser degree of comparability of non-tradables.

Hence, as from the theoretical point of view the maximization approach could be equally acceptable as the minimization approach, nevertheless the practical considerations favor the acceptance of the latter. Whatever the choice, what matters is the internal consistency between the model-assumptions and the model-conclusions, that characterizes he formalized approach, as opposed to the common inconsistencies of the traditional non-formalized approach used hitherto. Therefore the use of separate, mutually inconsistent partial incentive criteria or success indicators should be replaced by criteria derived from overall preference functions.

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[1] For the comprehensive list of possible preference functions, see, T. Koopmans and M. Montias, "Description and Comparison of Economic Systems," 1970, to be published.

## 9.3. Basic Problems of Applications

The transition from model analysis to macro-economic practical applications is connected with many difficulties and requires time. First the model-builder has to convince the policy-makers that the proposed changes will neither endanger the smooth functioning of decision-making processes, nor lead to unfeasible solutions. Hence the conclusions of the model analysis have to be translated into traditional instructions and illustrated by intuitive examples. The first practical step consists in the numerical determination of central parameters. On the basis of basic central parameters one can fix shadow prices, which, in turn, enable the statistical and plannistic determination of profits (or losses). Knowing approximately the potential consequences of the application of shadow prices for different sectors one can adapt the decision-making criteria so as to avoid not intended results. Correct central parameters are fully compatible with plans, but distorted parameters create conflicts between profit maximization and plan implementation, which may lead to intolerable consequences. In order to avoid great risks it is safer first to use shadow prices as obligatory analytical criteria and then, in the next period, to go over from analytical to decisional criteria. As long as the criteria are not connected with financial stimuli, the difficulty in applying new shadow prices on a macro-scale lies basically in the lack of experience as to the possible magnitude of profits or losses in particular sectors. Once one connects effectiveness criteria with financial stimuli--new problems arise. First, the new stimuli may give rise to unpredictable productivity increases, which may cause unexpected discrepancies in earnings. Second, the system of information on which the shadow prices,

profits and premiums are based, may be intentionally deformed at executive levels so as to influence the magnitude of expected premiums. A completely new administrative machinery has to be established within the framework of central planning, which should manage and control rates, prices and profits in an elastic manner, reacting on changes in external and internal conditions and adopting the system of stimuli and taxes accordingly. Hitherto there was no need and no experience within the traditional framework of central command-planning for this type of indirect guidance.

The use of the so called calculative approach means, that two parallel pricing systems are operating in the economy simultaneously. This duality of effectiveness and financial pricing creates several problems. In order to avoid these problems one is tempted to liquidate the duplicity and to connect the two pricing systems into a single one. However this creates new problems for planning and management. The existence of two separate pricing systems meant, that the calculative system reacted permanently to all changes, as the financial system was stable. All balances, success indicators, financial norms, wage constraints and accounting principles were relying on stable prices. The transition from stable prices to changing prices creates many problems. Should any change in external price of copper result in changes of prices in electrical equipment? If not, what deviations should be tolerable and how often should prices be recalculated? This type of problem has of course, no theoretical answer; only practical considerations can lead to a reasonable compromise between stability and elasticity.

Another aspect of the same dilemma is the degree of responsibility of various categories of staff for the fluctuations of profits (and thus premiums)

which occur beyond the sphere of competence of the staff ("speculative earnings or losses"). Again there seems to be no unique theoretical answer to such questions, however, it is clear that neither the existing solution, where the total responsibility rests with the state budget, nor the full transfer of all responsibility on the workers--could be treated as an acceptable solution.

Analogically, there seems to be no unique answer to the question: efficiency versus social considerations. Answers to these questions cannot be found in the model analysis, as they are, by nature, value judgments.

Another crucial question that faces the reformers is the extent of effective central price control. In conditions of non-competitive producers, possessing the exclusive control over their sphere of activity--central control of prices is clearly limited. Cost plus pricing rules cannot be affiliated with strong incentives based on profit maximization.

The list of similar questions and problems could be pursued further. However, the problems already listed suffice to illustrate the really great difficulties connected with the implementation of optimization models in practice and to explain the necessity for an evolutionary and pragmatic approach in economic reforms.

# PART III. PRACTICAL APPLICATIONS

## 10. Statistical Determination of Rates of Structural and Directions Effectiveness as Initial Rates of the Optimization Calculation for a Foreign Trade Plan

### 10.1. The Statistical Determination of $M^r$ and $K^r$

As already mentioned the statistical determination of rates of structural and directions effectiveness appeared to be the only available method for determining in practice the initial rates $M^r$ and $K^r$.

An additional argument in favor of determining $M^r$ and $K^r$ by statistical methods is supplied by the fact, that it is very difficult to include many treaty obligations within the central planner's calculations. On the contrary, the set of $M^r$'s and $K^r$'s determined by statistical methods contains these limitations which influenced definite planning decisions on the structure and directions of foreign trade.

There are bases for the claim that statistical determination of $M^r$ and $K^r$ is the first possible approximation to the optimum.

From our model considerations we know the behavior of $M^r$ and $K^r$ in the optimal solution. If one determined $M^r$ and $K^r$ from a completely arbitrary set, in which there are no relations between the rates and the structure of commodities and directions involved in trade, then the reasoning, based on the correctness of the optimal system would be meaningless.

It seems, however, that one can assume that the statistical solution is not very far from the optimal one, for the following reasons:

1. Although the commodity structure of exports, which has for many years been subject to careful analysis based on indices of effectiveness, is certainly not optimal, it nevertheless is not wholly composed of faulty items. Thus the set $M^r$, derived from such a structure is not arbitrary.
2. The directions structure of exports and of imports, realized on the basis of the policy of the Ministry of Foreign Trade should be close to the optimum. Minimizing costs to fulfil given targets expressed in foreign currency is equivalent to maximizing foreign currency earnings at given costs, i.e. to a tendency which has long prevailed in foreign trade planning practice.
3. Just as in a profit oriented competitive enterprise the stimulus of profit maximization leads towards solutions close to the optimum, similarly in our foreign trade the tendency to optimize directions policy should lead to solutions, which statistically are not far from the optimal one.

Those arguments indicate, that the sets $M^r$ and $K^r$, derived statistically, can be treated as a first approximation towards the optimal set.

The theoretical considerations presented in paper[1] lead to the conclusion, that in the optimal solution $M^{Er} = M^{Ir} = M^r$; that $K^{Er} = K^{Ir} = K^r$; and that $K^{r''}/K^{r'} = M^{r''}/M^{r'}$.

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[1] W. Trzeciakowski: Model optymalizacji biezacej polityki kierunkowej w handlu zagranicznym. Gospodarka Planowa Nr 8-9, 1960.

Thus, if we assume, on the basis of previous considerations, that the current solution is a certain approximation to the optimum solution, then we can determine the rates $M^r$ and $K^r$ by statistical methods, based either:

--on an analysis of exports only,

--or on analysis of exports and imports.

If the analysis of the results of both sets leads to discrepancies, and both sets from the statistical point of view are correct, then the discrepancy is the measure of the deviation of the existing solution from the optimum. In this case we shall seek the optimum $M^r$'s and $K^r$'s in between $M^{Er}$, $K^{Er}$ and $M^{Ir}$, $K^{Ir}$ while to determine the numerical values of $M^r$ and $K^r$, as an average of the exports and imports data, we can weigh both sources of information by the degree of their statistical reliability.

If on the other hand we judge, that from the statistical point of view the reliability of one of the sets is doubtful (e.g. owing to deformation of the costs of production for export purposes), or owing to noncomparable prices of imports (expressed in foreign currency), then we can rely on one set only, i.e. on the less deformed one. Our choice is completely free in computing $K^r$ (i.e. exports or imports or both), but in computing $M^r$ this freedom is limited by the inadequacy of import prices expressed in terms of zlotys (i.e. exports, or exports and imports).

The choice of the procedure depends on the kind of statistical material available and on treaty conditions concerning a given country.

Statistical considerations concerning both sets are presented below.

## 10.2 Statistical Analysis of Export Rates[1]

On the basis of the statistical analysis of about 25,000 series of data, concerning various commodities on separate markets, initial statistical tables and the following parameters are computed:

-- the average foreign exchange rates for exports attained on separate markets (measured in F )

-- the average rates of the marginal decimal (measured in F )

-- the correction for the marginal decimal, resulting from the substitution of the price expressed in zlotys F by corrected computer costs, or by full processing costs, i.e. KWB .[2]

On the basis of statistical data graphs are prepared presenting the rates $M^{Er}$ for exports to separate markets. The volume of exports expressed in "foreign currency zlotys" is presented on the abcissa and final rates for separate commodities are presented on the vertical axis; exports to a given market are ranged according to growing rates.

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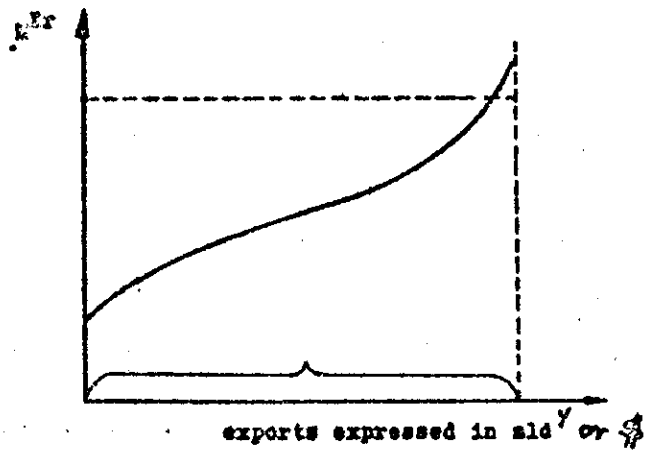
[1] A separate study, prepared by the Study Group on Effectiveness of the Foreign Trade Research Centre, presents yearly an analysis of statistical data.

[2] The tables are prepared on the basis of indices used up the present in foreign trade, i.e. F , KWB and L :

F - Financial Indicator, determining the ratio of the domestic price (in zlotys) to the price in foreign currency,

KWB - Financial Corrected Indicator, differing from F by the amount of accumulation, in the last processing phase,

L - Last Phase Labor Indicator, which is the ratio of processing costs (in zlotys) of the last phase, to the net gain in the price obtained in foreign currency, deduction made of the value of material outlays expressed in foreign currency.




Now there arises the problem of the choice of the marginal value. Various solutions are possible:

a) on the basis of the existing graph we determine the value of $M^r$, at the point of intersection of the last but one section (e.g. decimal) with the value of our export to a given market,

b) we can also straighten the curve along its tangent in the last section and find its intersection point with the value of our exports.

The general rule is, that in order to eliminate the influence of marginal (incidental) transactions, the marginal value is taken as the average of the last part of the export curve for a given market, and in doing so its individual shape is considered.

Marginal rates, obtained from statistical procedure, can also be verified from the point of view of changes of $M^r$ over time. Comparing similar statistical analyses the formation of marginal rates in consecutive time periods can be observed. Statistical data for 10 consecutive years show a remarkable stability of $M^r$ for large markets.

For exports to small markets, where oscilations of marginal values over time are sometimes substantial, it is better to determine those values on the basis of average data.

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1/ 1 $ = 4 zld .

In considering such markets one determines the relation between the marginal rate of exports $(M^r)$, and the average rate of exports $(W^r)$ during consecutive periods (years), according to the formula:

$$A = \frac{\sum_t \frac{M_t^r}{W_t^r} \cdot Q}{\sum_t Q_t}$$

where: $t = 1960, \ldots, 1970$

$Q$ = exports to market $r$ in zlotys expressed in foreign currency in year $t$.

In this case the final value of $M^r$, determined statistically, will be: $W^r \cdot A$, i.e.

$$M^{Er} = W^r \cdot A$$

Having a statistically determined set of structural and directions rates of effectiveness $M^{Er}$, we can also determine, as a first approximation, the set of rates of directions effectiveness $K^r$ as:

$$K^{Er} = \frac{M^{Er}}{M^{Eo}}$$

To avoid substantial deviations of such a set from the optimum, due to incidental statistical value of $M^{Eo}$, $M^o$ can be determined through the set $K^{Ir}$ for imports, according to the method described below.

It seems necessary for the application of statistically determined $M^{Er}$'s to optimization problems of the foreign trade plan, to introduce additional

corrections in order to take into account the conditions of convertibility of foreign currencies.

When, between the given countries, currency is convertible, and when there are no quantitative limitations on this convertibility, the marginal rate for such countries should be equal. Such a rate is obtained from a graph prepared jointly for all such countries (e.g. for the countries of the European Economic Community).

If the transfer of currencies is possible in one direction only, from market 1 to market 2 (without disagio), then:

$M^1 \geq M^2$ - if such an alternative is not actually applied,

$M^1 \leq M^2$ - if such an alternative has actually been applied,

$M^1 = M^2$ - if transfer possibilities are unlimited.

If the convertibility of the currency of market 1 into currency of market 2 is possible under a certain disagio (d), then in the conditions given above: instead of $M^2$ should be written $(1-d)M^2$.

On the basis of the above principles the rates of structural and directions effectiveness for 1961 were first determined, and then collected systematically on a yearly basis.

The rates $M^r$ and $K^r$ determined in such a way can then be submitted to a plannistic checking.

Since the major part of foreign trade is based on existing treaty obligations, and since in many cases actual alternatives for increasing foreign trade relations are already known, further preliminary corrections of statistical rates can be based on preliminary, planning evaluation of the conditions

of trade relations with a given market for the coming period. Such an evaluation flows from existing or anticipated treaty obligations, from changing foreign exchange tasks, and the commodity structure of foreign trade, and also from the changes of prices expressed in foreign currency. In other words the $M^r$ and $K^r$ curves may be re-shaped, if anticipated future changes are expected to influence the values of the new shadow prices. In such corrections it is essential that the marginal rate $M^r$ corresponds to the actual alternative of the anticipated increase (or decrease) of foreign trade.

Thus, beginning with an analysis of statistical values, and introducing changes of the rates over time and anticipated changes of trade conditions in the following year, we obtain the initial set $M^r$ and $K^r$, which can be taken as the initial optimization of the plan.

## 3 Statistical Determination of the Rates for Imports

The determination of rates, resulting from the import structure will now be considered. It would make no economic sense to determine $M^{Ir}$ on the basis of domestic prices expressed in zlotys, and determined till 1970 arbitrarily for imported commodities.

For this reason it seems advisable to refer to the set $K^{Ir}$ which can be determined by a comparison of actual prices expressed in foreign currency (of the given market) with free currency prices. Such indices have economic meaning for imports, since the possibility of purchases on the free currency market is, as a rule, an actually existing alternative for most of the com-

modities imported to any country.[1]

This supports our opinion that the so-called indices of the relative value of a currency are a proper basis for determining the set $K^{Ir}$ for imports. By $K^{Ir} = 1$ we understand $K^{r}$ for the free currency market.

The reasoning is based on the assumption, that the actual solution in the field of imports is close to the optimal one. If so, then the following condition for imports is fulfilled:

$$\frac{d_k^{Ir} \cdot K^r}{d_k^{Io}} \leq 1 , \quad \text{and thus:} \quad K^r \leq \frac{d_k^{Io}}{d_k^{Ir}}$$

where: $d_k^{Ir}$ - price of commodity $k$, imported from market $r$,

$d_k^{Io}$ - import price of commodity $k$ on the free currency market.

The above condition is not fulfilled when there is no alternative possibility of additional purchases of certain commodities (e.g. embargo). Such commodities should be omitted in statistical analysis.[2]

Thus, having indices for many commodity groups $k$, we can range them according to their diminishing values.

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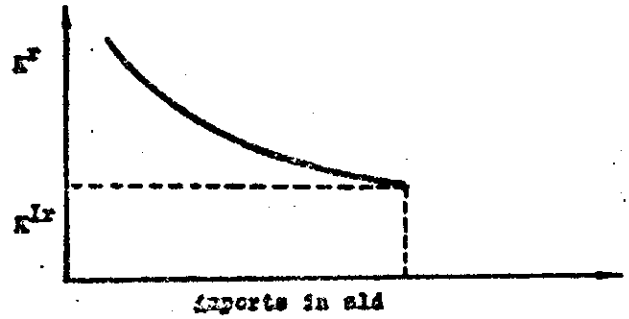
[1] While for exports, the assumption that all commodities which one wishes to sell can be sold on the free currency market is unrealistic.

[2] It is impossible to set up a similar condition for exports: $K^r d_k^{Er} \geq d_k^{Eo}$, because the sale of all our commodities on the free currency market is an unrealistic assumption.

Market r. Dependence of $K^r$ on the value of imports




We determine the marginal value of $K^{Ir}$ by methods similar to those used to determine $M^{Er}$ (by the graphic method described above, or as the algebraic mean of the marginal sector).

NOTE 1. We can take as the basic market either one of the actually existing free currency markets, e.g. the United States, where practically everything can be purchased, or else we can "create" such a market, aggregating West European markets with those of the United States and Canada. In the first case, $K^r$ for separate West European markets will be differentiated, in the second it will be equal to unity. Since the assumption, that everything can be purchased on West European markets is close to reality (since currencies of those countries are convertible), we actually base our optimum solution for imports on the marginal value $K^r = 1$ (this is not equivalent to saying, that average values for imports from these markets cannot be differentiated). Actual statistics of indices of relative value of currencies are also based on this assumption. Since this assumption is close to reality, and since it plays a special part in the system of the indices of the relative value of currencies, the aggregated market is taken as basic in further considerations.

Having the set $M^{Er}$ and the set $K^{Ir}$, we compute for each market the ratios $M^{Er}/K^{Ir}$, which according to our model should be equivalent to: $M^{Io} = M^{Eo} = M^{o}$, since in the optimal solution:

$$\frac{M^{Er}}{K^{Ir}} = \frac{M^{r}}{K^{r}} = M^{o}$$

In order to eliminate incidential elements in these ratios for a given market we compute weighted averages of these ratios for all markets, obtaining the average:

$$\overline{M}^{o} = \frac{\sum_{r} \frac{M^{Er}}{K^{Ir}} \cdot Q^{r}}{\sum_{r} Q^{r}}$$

where: $Q^{r}$ - trade with market $r$ expressed in zld.

Having $\overline{M}^{o}$, we can compute the set $K^{Er}$ on the basis of

$$\frac{M^{Er}}{\overline{M}^{o}} = K^{Er}$$

NOTE 2. If the sets $K^{Er}$ and $K^{Ir}$ are close to each other, it is a sign, that the statistical solution is close to the optimum.
The more the sets $K^{Er}$ and $K^{Ir}$ diverge from each other, the farther is the existing solution from the optimum.
The deviation can be measured as follows:

$$\left| \frac{K^{Er}}{K^{Ir}} - 1 \right| , \text{ i.e. } \left| \frac{M^{Er}}{\overline{M}^{o} K^{Ir}} - 1 \right| = \left| \frac{\frac{M^{Er}}{K^{Ir}} - \overline{M}^{o}}{\overline{M}^{o}} \right|$$

The average deviation of the whole set can be determined by the following formula:

$$\gamma = \frac{\left| \sum_r \frac{M^{Er}}{K^{Ir}} - \overline{M}^o \right| \cdot Q^r}{\overline{M}^o \sum_r Q^r}$$

The value of the above expression gives a general idea of the degree of deviation of the statistical set from the optimum position, for separate markets, and for the overall position.

Thus, we obtained the sets of rates $K^{Ir}$ and $K^{Er}$. Now, we proceed to determine the set $K^r_{opt}$, in order to determine $M^r_{opt}$, on the basis of $M^o$ and $K^r_{opt}$, according to the formula: $M^r_{opt} = \overline{M}^o \cdot K^r_{opt}$.

NOTE 3. It may be doubted, whether it is admissible to compare the curves of structural and directions rates for exports $(M^{Er})$ with the curves of directions rates for imports $(K^{Ir})$, since the latters are determined by foreign currency price ratios only $(d^{Io}_k : d^{Ir}_k)$, and thus it seems that they do not contain the elements of effectiveness of the commodity structure.

The proof, that the model of directions optimization is a part of the model of structural and directions optimization, i.e. that $K^{Er} = K^{Ir} = K^r$ and $M^{Er} = M^{Ir} = M^r$ was presented in paper.[1]

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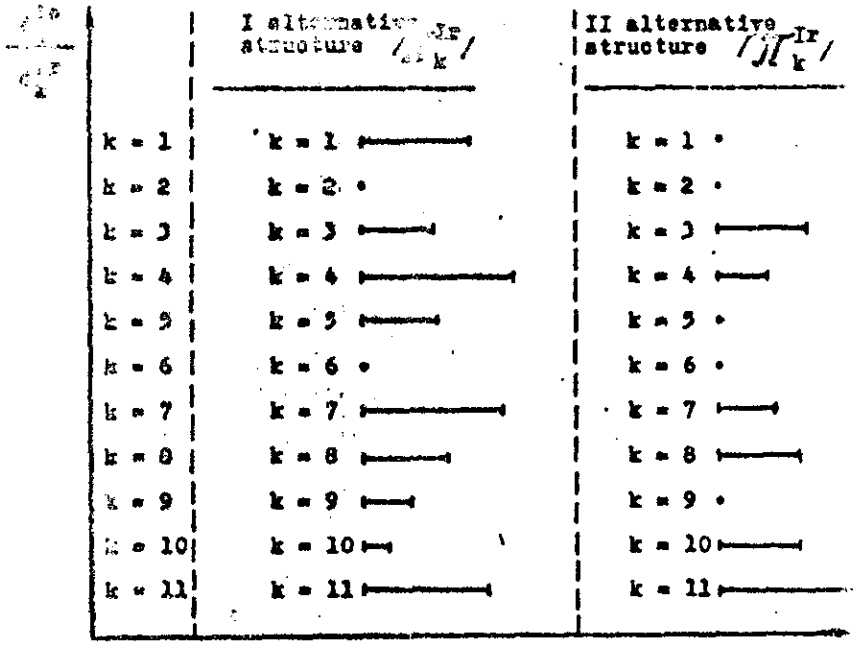
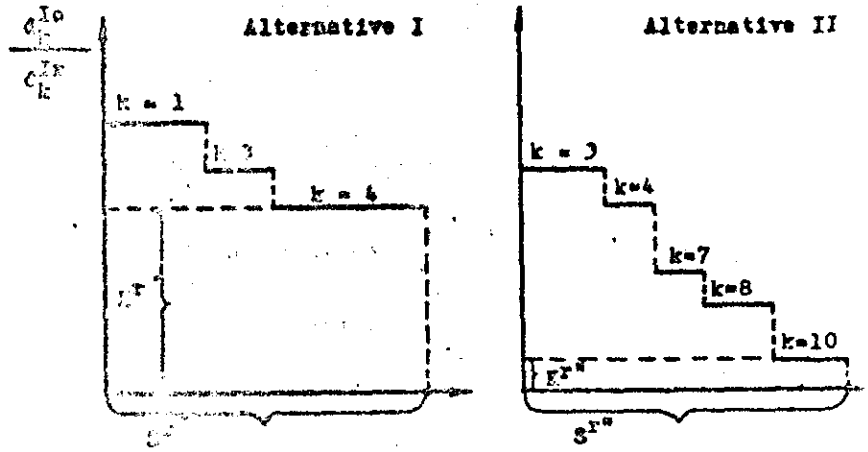
[1] W. Trzeciakowski: Problemy kompleksowego systemu analizy efektywnosci biezacej handlu zagranicznego, Studia Komitetu Przestrzennego Zagospodarowania Kraju PAN tom II, Warszawa, 1961.

However, apart from the mathematical proof it can be shown, that the curve of import rates also expresses the commodity structure shaped by restrictions on supply.

Having equal prices expressed in foreign currency, and equal tasks concerning foreign currency $S^r$, different shapes of the curve and different values $K^r$ are obtained.



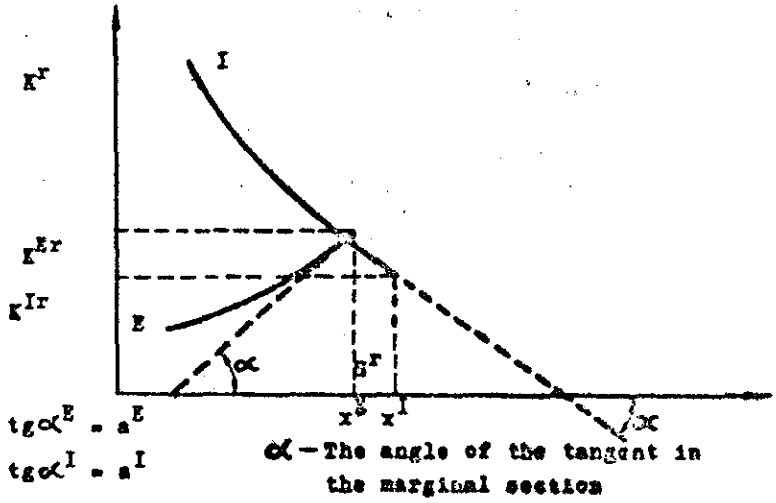



The set $K^r_{opt}$ can be determined:

a) either through investigation of the gradients of the tangents to the import and export curves in points $K^{Ir}$ and $K^{Er}$,

b) or by graphical methods, taking into account the planned balance $S^r$.

The gradient of the tangents to the import and export curves in points $K^{Ir}$ and $K^{Er}$




The equations for the tangents of exports and imports in points $K^{Er}$ and $K^{Ir}$ are given:

for exports $K^r = K^{Er} + a^E(x - x^E)$

for imports $K^r = K^{Ir} - a^I(x - x^I)$

We postulate, that: $K^r_{opt} = E^{Er}_{opt} = K^{Ir}_{opt}$

We should find $x_{opt}$ for $K^r_{opt}$ from both equations

$$K^{Er} + a^E(x^E_{opt} - x^E) = K^{Ir} - a^I(x^I_{opt} - x^I)$$

The balance $S^r$ should stay in the optimal solution:

$$x^E_{opt} - x^I_{opt} = S^r \ .$$

The above condition is also true for $x^E - x^I$, i.e.

$$x^E - x^I = S^r$$

$$x^E_{opt} = x^I_{opt} + S^r \ , \quad \text{and}$$

$$x^E = x^I + S^r$$

$$x^E_{opt} - x^E = x^I_{opt} - x^I$$

$$K^{Ir} - K^{Er} = a^I(x^I_{opt} - x^I) + a^E(x^I_{opt} - x^I) = (a^I + a^E)\cdot(x^I_{opt} - x^I)$$

$$x^I_{opt} - x^I = \frac{K^{Ir} - K^{Er}}{a^I + a^E}$$

$$K^r_{opt} = K^{Ir} - a^I \frac{K^{Ir} - K^{Er}}{a^I + a^E} = \frac{K^{Er}a^I + K^{Ir}a^E}{a^I + a^E}$$

This leads to the conclusion, that the value $K^r_{opt}$ does not depend on $S^r$, $x^I$ or $x^E$, but only on the values of $K^{Er}$ and $K^{Ir}$ and on the gradient of the tangents in the marginal sector.

Now let us analyze the results obtained.

The line for imports on the basic market (market 0) is horizontal, that is to say: $a^I = 0$.

Thus:

$$K^o_{opt} = \frac{K^{Io}a^E}{a^E} = K^{Io} = 1$$

as can be seen, the value of $K^{Eo}$ derived from $M^{Eo}/M^{o}$ does not influence $K^{o}_{opt}$.

The gradient of the curves for other markets is generally greater for higher rates so that it seems expedient to accept the assumption:

$$\frac{a^E}{a^I} = \sqrt{\frac{K^{Er}}{K^{Ir}}}$$

Thus:

$$K^{r}_{opt} = \frac{K^{Er}a^I + K^{Ir}a^I\sqrt{\frac{K^r_E}{K^r_I}}}{a^I + a^I\sqrt{\frac{K^{Er}}{K^{Ir}}}} = \frac{K^{Er} + \sqrt{K^{Er}K^{Ir}}}{1 + \sqrt{\frac{K^{Er}}{K^{Ir}}}} =$$

$$= \frac{K^{Er}K^{Ir}\left(\sqrt{\frac{K^{Er}}{K^{Ir}}} + 1\right)}{1 + \sqrt{\frac{K^{Er}}{K^{Ir}}}} = \sqrt{K^{Er}K^{Ir}}$$

As can be seen, having $K^{Er}$ and $K^{Ir}$, $K^{r}_{opt}$ may be obtained as their geometric average mean.

But if the shape of the export and import curves for market $r$ $(r \neq 0)$ leads to the assumption, that the angles of the tangents in the marginal sections are symetrical, i.e., that:

$$a^E = a^I,$$

then

$$K^{r}_{opt} = \frac{K^{Er} + K^{Ir}}{2}$$

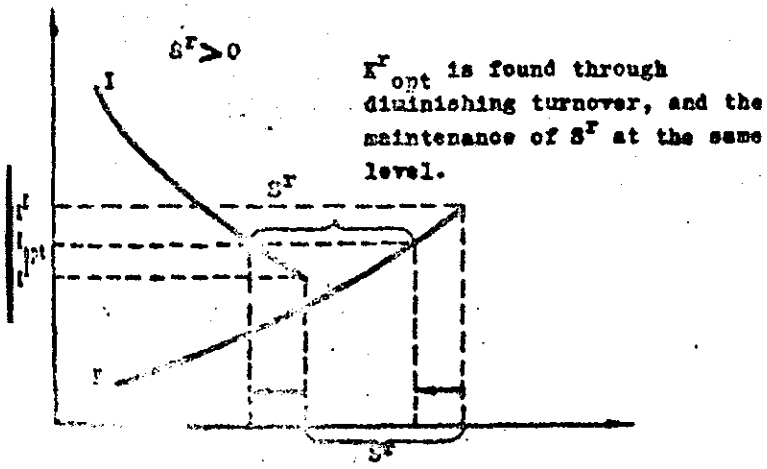
Thus we obtain $K^r_{opt}$ as the arithmetic mean of $K^{Er}$ and $K^{Ir}$.

## 10.4. The Graphic Method for Determining Optimal Rates Including the Planned Balance $S^r$

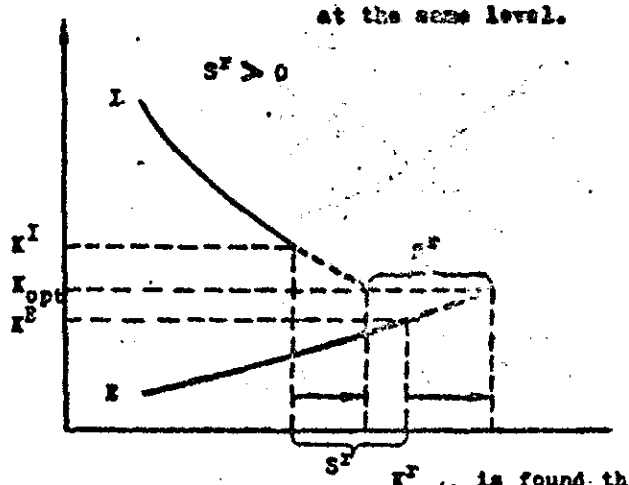
Assuming a given balances for market r, i.e. $S^r$, and knowing that: $K^{Er}_{opt} = K^{Ir}_{opt}$, the value of $K^r_{opt}$ can be determined using graphical methods.

In order to do this, we should adjust imports and exports in such a way as to reach the points at which $K^{Er} = K^{Ir}$, without changing the balance assumed previously.

The following cases can be presented as exemplification of the method:

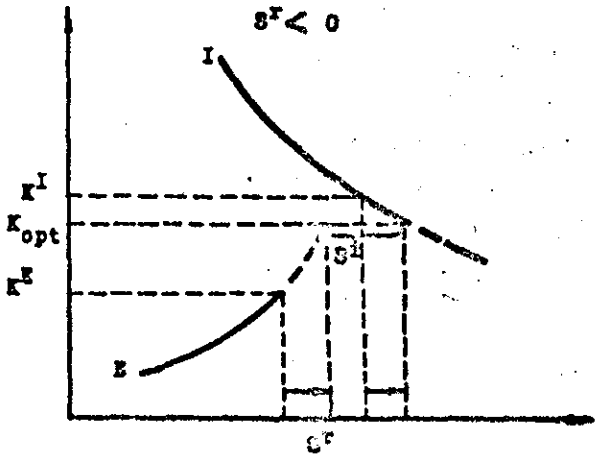



$K^r_{opt}$ is found through diminishing turnover, and the maintenance of $S^r$ at the same level.

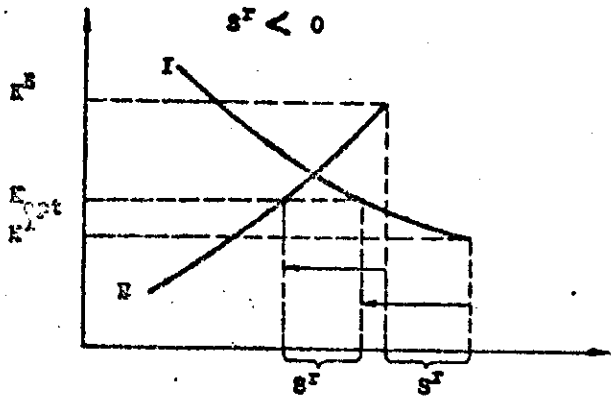



$K^r_{opt}$ is found through increasing turnover, and the maintenance of $S^r$ at the same level.

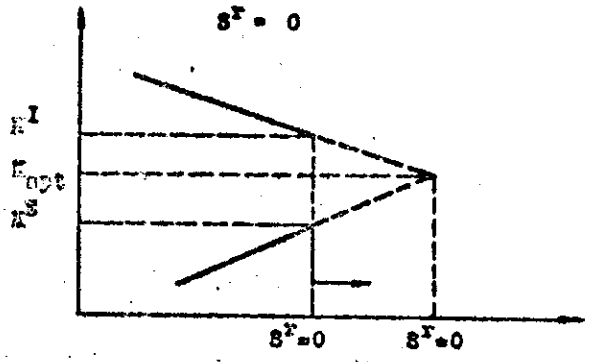
$K^r_{opt}$ is found through increasing turnover.



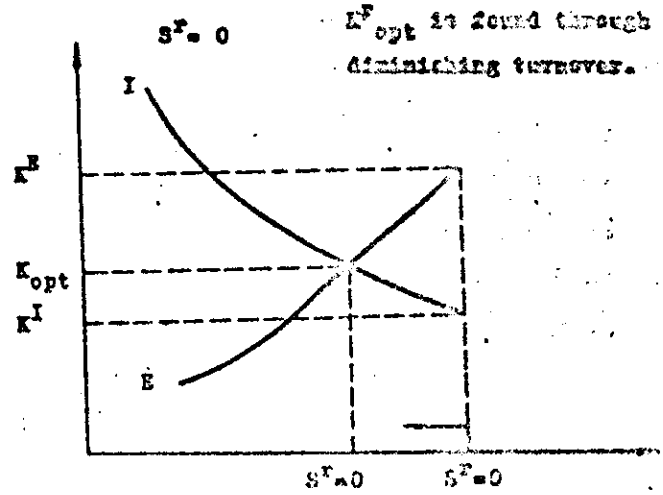
$K^F_{opt}$ is found through diminishing turnover.




$K^F_{opt}$ is found through increasing turnover.




$K^F_{opt}$ is found through diminishing turnover.



Thus, using algebraic or graphical methods we have determined the value of $K^r_{opt}$. Having $K^r_{opt}$ and $M^o$ we can in turn determine the set $M^r_{opt}$ as:

$$M^r_{opt} = \overline{M}^o \cdot K^r_{opt}$$

Thus, beginning with the statistical sets $M^{Er}$ and $K^{Ir}$ we arrive at the sets $K^r_{opt}$ and $M^r_{opt}$.

It is obvious, that those last sets should be treated not as the planning optimum, but only as first approximation to such an optimum, since they are the starting point of an iterations procedure which leads to the optimum planning solution.

By a method similar to the one used in considering the rates derived from exports, we can preliminarily verify our initial rates on a planning basis. Then, our curves of the import and export rates should be corrected according to the new planning premises, such as:

-- the assumed (or anticipated) balance with a given market,

-- changes in the commodity structure, according to treaty obligations,

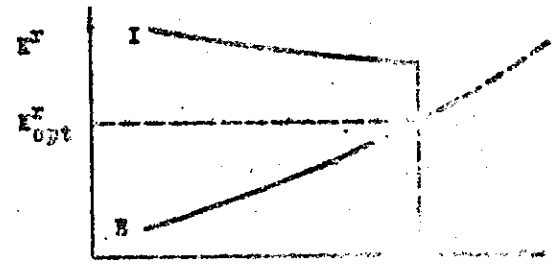
--changes in the parameters of the calculations (such as demands, supplies, and prices).

Thus, determined sections of the curves, and their extrapolations may be subject to change. The graphs of import and export rates should present real alternatives for increasing turnover, based on current anticipations.

Such a procedure can take into account the following, extreme cases:

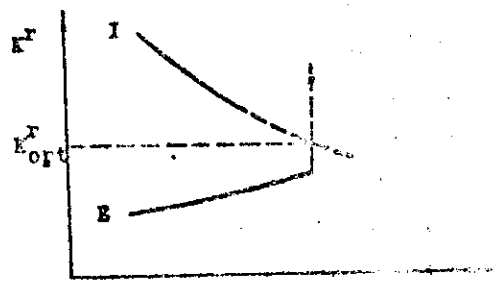
1. We may increase both imports and exports and in this case the solution can be reached by algebraic or graphical methods extrapolating the existing curves (as above).

2. On a given market it is possible to sell more, but it is impossible to buy more; in this case the curve of export rates can be extrapolated, while the curve of import rates drops perpendicularly (i.e. the price of further imported items tends towards infinity, and the rate tends towards zero). In this case $K^r_{opt}$ is determined by the export rate.




exports, imports in cli.

3. On a given market we can buy everything, but we cannot increase our exports. The curve of import rates can be extrapolated, but the curve of export rates goes straight upwards (i.e. the price of further items exported falls to zero, and the rate tends to infinity). $K^r_{opt}$ is determined by the import rate.




exports, imports in cli.

4. If it happens that neither exports nor imports can be increased for a given market the rate will remain undetermined between $K^{Er}$ and $K^{Ir}$, while for the optimization calculation the value of $K^{r}$ is irrelevant.

The solutions presented above lead to the conclusion that the determination of the optimum should be based on "planning curves," and that such a procedure may lead to additional corrections of the initial system of rates $M^{r}$ and $K^{r}$. Such a procedure is naturally not a substitution for the iterations procedure of preparing the plan itself, since the choice of optimal solutions must reflect all changes in the mutually interconnected markets and not only changes in one geographical direction. Nevertheless the planning correction of curves, based on predetermined treaty, structural, price premises, etc. may be an essential contribution in improving the inidial optimization parameters. The rest must be left to the living and huge "traditional computer," encompassing thousands of decision-makers at various levels of planning and management.

## 10.5. Methods of Determining the Marginal Rate of Interest on Fast Recouperating Investments Connected with Foreign Trade

A given investment fund is determined by the Central Planner for a given plan period to the disposal of the Ministry for Foreign Trade to improve the balance of payment. (This fund is treated separately from the allocation of basic investment funds for general development, which are allocated directly by the Central Planner.) The Ministry of Foreign Trade applies then the following procedure:

1) Industrial Trusts are asked to apply for funds and requested to construct the following indexes:

$$\alpha_i = \frac{\sum_r M^r D^r - C}{I}$$

where $\sum_r M^r D^r - C/I$ = profit over investment inputs as explained in Part II chapter 7.

2) The Ministry of Foreign Trade on the basis of requests received ranges the proposals according to the decrescent index. The last project for which investment funds are still available becomes the marginal value of $\alpha$.

3) The value of $\alpha$ is then inserted in other formulas described in the following chapter. It is obvious that the value of $\alpha$ is determined by the magnitude of investment funds allocated for the given period at the disposal of the Ministry of Foreign Trade. Hence the value may be changed accordingly to the changes of available funds for the short-run improvement of the balance of payment.

## 11. Effectiveness in Planning.

### 11.1. The General Directives of the "Kalecki Commission." [1]

The general considerations of the model analysis presented in chapters 5 and 6 have been accepted and the following conclusions have been formulated:

1. The marginal rate M should be a function of actual commodity-- and foreing currency plan targets.
2. The set of $M^r$ and $K^r$ should be differentiated for various geographical directions.
3. The basic criterion of choice for executive levels should be the maximization of profit criterion, i.e., $\sum_r M^r D^r - C$ (as discussed in detail in Part II, chapter 6).
4. Statistical rates $M^r$, based on past periods, should be used as the starting value for the optimization calculus in the planned period. These initial values should be corrected in accordance with the planned changes of foreign currency targets, changes in the commodity structure of foreign trade and expected changes in foreign supply, demand and prices.
5. The determination of $M^r$ and $K^r$ should become an integral part of the planning process.

On the basis of centrally determined $M^r$ and $K^r$ and structural export-- and import constraints--foreign trade and industrial enterprises work out

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[1] In 1961-1963, a Governmental Commission presided by Prof. M. Kalecki, analyzed the Optimization Models presented in chapters 5 and 6 and issued the above general methodological directives im the form of an official decree. [Wytyczne Komisji Do Oceny Metod Badania Efektywnosci Handlu Zagranicznego-- Chapter 5 in Efektywnosc Handlu Zagranicznego, PWE, Warszawa 1969, pp. 333-337.]

effectiveness calculations and:

a. select plan variants,

b. compute the Effectiveness Indicators $E_k^r$

c. formulate export proposals (for particular currency markets) aggregated in foreign currency ranged for consecutive values of $E_k^r$ (only centrally non-specified plan items are accordingly aggregated; specified items in the central plan are dealt with separately, stating the export value and the $E_k^r$ indicator).

d. work out import proposals from particular foreign currency markets.

On the basis of (c) and (d) the Central level works out the geographical allocation of exports and imports:

a. ranging (for particular markets) aggregated commodity proposals according to the growing indicator $E_k^r$

b. balancing particular markets, taking into account as well the indicator $E_k^r$ as also the structural treaty limitations and interdependencies between exports and imports in clearing arrangements.

As a result, new values of $M^r$ and $K^r$ are obtained for the next plan-period.

6. a. To facilitate the practical calculation of effectiveness for decision-making in planning shadow price catalogues should be elaborated and periodically revised.

b. To strengthen the effectiveness criterion in decentralized decision-making--a system of incentives based on the profit

maximizing criterion should be introduced in foreign trade, and industrial enterprises working for exports.

c. Effectiveness calculations should be connected with the the financial system in foreign trade; specifically imported goods and scarce raw materials should be priced in accordance with effectiveness considerations.

d. Effectiveness considerations should be built into the procedures of elaboration of treaty policies, and treaty negotiations, as well as credit policy and payment policy formation.

e. Electronic computing centers should adopt the plans to the requirements of the elaboration of foreign trade policy at the central, sectoral and enterprise level.

This first set of governmental official directives dealing with the introduction of effectiveness criteria in planning and management and issued under the auspices of the chairman of the Planning Commission were formulated in full conformity with the theoretical conclusion of the model analysis. Further official decrees and instructions dealing with consecutive stages of practical implementation of these objectives contained several formulations which deviated from the more theoretical approach. The evolution of the initially analytical system into a decisional one has been accompanied by a growing influence of non-model considerations. The more powerful in terms of decision-making the system became, the more deviations from pure theoretical reasoning were implanted into it. The trade-off between theoretical purity and practical feasibility takes often the dangerous form of a trade-off between

the systems' logic and internal consistency and the neglect of it for the sake of simplicity of the system. Needless to say, that seemingly simple but inconsistent partial solutions lead to tremendous complications of the over-all system; however, this becomes apparent at a later stage of implementation (false partial criteria require the introduction of corrective systems, which, as a rule, are much more complicated then the original adequate rules).

The general consistency of a decisional system of indirect planning and management with the system of centralized commands has nothing to do with a mechanism of self-regulation. This indirect mechanism (central parameters of the system) has to be under constant control and must be regulated by the Central Planner. If there is nobody to defend the internal consistency of the functioning of the system, the system must collapse. The understanding of this trivial truth is not commonly accepted. On the one hand, there are those who are looking at effectiveness systems as on partial incentives, which need not bother with the overall consistency of the rest of the economy. On the other hand, there are those who believe still in the invisible hand of self-regulatory processes, relying on the functioning of wise rules, determined once and for all. However, the hand must be visible, conscious of its aims and determined to act so as to preserve the internal logic of the functioning of the system. This set of requirements is not easy to be met in practice, and requires, as is often called, a higher "Culture of Planning."

## 11.2. The Profit Maximization Criterion In Decentralized Planning.

The use of success indicators of the quotient type is deeply rooted

into the habits of central decision-making. The very simple reason for it is that at the Central level activities can be ranged according to a quotient indicator whereas profits cannot be compared at the Central Macro-level. In principle, the introduction of profit maximizing criterion is justified when decentralized decision making is assumed. However, the final decision as to whether to eat the cake or to enjoy preserving it is not an easy one. Hence, if external conditions do permit, it is likely to be postponed. Thus, it is often argued that the preservation of central effectiveness quotient indicators is safer as the introduction of the criterion: $\sum_r M^r D^r - C = \max$, solely in the form of an appeal or command, without any sanctions whatsoever, will not operate in practice. Still attempts have been made to introduce it. In the first stage of implementation of the profit maximization criterion there were various attempts to apply it to industrial trusts working for exports. The adoptation of operational research techniques to practical optimization problems of industrial trusts has been implemented in practice by interdisciplinary teams. 1/

General Central parameters $M^r$ and $K^r$ were determined by the Central Planner, as discussed in chapter 10. In order to determine prices of basic raw materials coming to the industrial trust from outside, the Central Planner had to define rules of shadow prices formation and to establish an informational network, that could enable the practical pricing of materials.

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1/ For a detailed description see: W. Piaszczynski: Optymalizacja Wymiany Z Zagranica W Grupach Dzialalnosci Wspolzaleznych in: Efektywnosc Handlu Zagranicznego, PWE, Warszawa 1969. Each team encompassed speialists from various branches: Central planner, general economists, mathematicians, branch-planners of foreign trade, branch-planners of industry, enterprise accountants and statisticians.

From the general analysis of the properties of the optimal solution of the General Model of Commodity Structure and Geographical Allocation and of the Model of Fast Recouperating Investments, we can formulate the following relationships:

-- for exports:

$$l_k = M^r d_k^{Er} - N^{Er} \qquad \text{if } Y_k^{Er} = \pi_k^{Er} ;$$

$$\text{if } 0 < y_k^{Er} < \pi_k^{Er} \text{ then } N_k^{Er} = 0 ;$$

(where $N_k^{Er}$ is the rent of the foreign demand constraint).

-- for imports:

$$l_k = M^r d_k^{Ir} + N_k^{Ir} \qquad \text{if } Y_k^{Ir} = \pi_k^{Ir}$$

$$\text{if } 0 < y_k^{Ir} < \pi_k^{Ir} \text{ then } N_k^{Ir} = 0$$

(where $N_k^{Ir}$ is the rent of the foreign supply constraint).

-- for domestic production:

$$l_k = \sum_j a_{jk} L_j + C_k + G_k \qquad \text{when } x_k = b_k ;$$

if $0 < x_k < b_k$ then $G_k = 0$ ;

$$G_k \geq \alpha I_k$$

(where $G_k$ is the rent of the production capacity constraints).

Knowing:

-- the set of marginal rates $M^r$ ;

-- foreign prices in exports $d_k^{Er}$ and in imports $d_k^{Ir}$ ;

-- domestic costs: processing costs $C_k$ and material inputs $\sum_j a_{jk} l_j$ priced in term either on the basis of foreign prices or domestic costs;

-- the marginal interest rate $\alpha$ , determined as a marginal rate of profitability;

-- investment outlays $I_k$ leading to a unit increase of the productive capacity;

-- the actual (or expected) foreign demand $\pi_k^{Er}$ and supply $\pi_k^{Ir}$ in relation to productive capacity,

one can find out the first approximation of the values of shadow prices for individual commodities.

On the basis of marginal currency rates $M^r$ fixed by the Central Planner and the prices of materials determined in accordance with the rules described above--operational research techniques were applied, using electronic computers, and reaching improvements of the traditional solutions ranging from 12% to 15%. They were applied as well to export production as to import substitution. The results achieved were also helpful in evaluating the consequences

of changes of Central parameters on the commodity structure of exports and imports. As long as these optimization calculations were promoted by the Central Planner, there were no obstacles in implementing them in practice. But as long as there were no incentives connecting the improvements reached with the system of premiums, the application of these methods was limited to a few imitatives. Only when the incentive system has been introduced (see next chapter) the situation changed. The use of operations research became widely spread and the initiative for the implementation of optimization calculations came from executive (enterprises--industrial trust) levels. This showed the importance of motivational factors for the decentralization of decision-making to become successful.

## 11.3. The Central Effectiveness Indicator $E_k^r$ .

The central level needs an instrument which will indicate which elements of the preliminary plan-proposals submitted by the executive level should be eliminated. Indices expressed as fractions can be adequate for this purpose, since they can serve as a means of ranking commodities belonging to various groups of interrelated activities, i.e. for the comparison of various groups (since outputs of different branches or groups are not, as a rule, competing for the same material inputs). It follows that the central level requires an index which can be computed for all commodities (or for a large number of sample commodities), and which should be capable of performing the following functions:

-- bringing up to date the $M^r$ rates;

-- verifying the use of the optimization criterion at the executive level;

-- ranking of all commodities (or samples) from various groups and the eliminating of non-profitable items, as well as the eveluation of the overall commodity and the directional structure of the central foreign trade plan.

Such a coefficient of effectiveness $E$ for commodity $k$ on market $r$ is written as:

$$E_k^r = \frac{c_k'}{K^r \; d_k^{Er}} \quad , \quad \text{or} \quad E_k^r = \frac{c_k'}{K^r \; d_k^{Ir}} \; ,$$

where:

$c_k'$ - total unit costs of commodity $k$, expressed in domestic currency, comprising labour costs and costs of material inputs;

$K^r$ - rate of directional effectiveness for market $r$ ($r = 0, 1, \ldots, s$), expressing the ratio between the marginal rate for this market currency ($M^r$) and the marginal rate of the basic market currency ($M^o$);

$d_k^{Er}$, $d_k^{Ir}$ - average price expressed in foreign currency of commodity $k$ ($k = 1, \ldots, m$), obtained for exports (f.o.b.) to market $r$ (in cases of import substitution);

The calculation of $c_k'$ (the numerator of the coefficient $E_k^r$) proceeds as follows:

1. labour costs are assumed on the basis of data obtained from calculation of the enterprise's own costs;
2. costs of material inputs are calculated on the basis of

-- $M^r d_k^{Er}$ - i.e. on the basis of the product of the marginal rate of the given market and the export price (f.o.b.) expressed in foreign currency for these material inputs which are exported (and exports of which may also be increased). If several markets are considered, the lowest product $M^r d_k^{Er}$ is accepted;

-- $M^r d_k^{Ir}$ - i.e. on the basis of the product of the marginal rate of the given market, and the price paid for imports (c.i.f.) expressed in foreign currency, for these material inputs which are imported (and imports of which may be increased). If several markets are considered, the highest product $M^r d_k^{Ir}$ is, as a rule, accepted;

-- costs in domestic currency (or on the basis of domestic prices) in all other cases.

The index $E_k^r$ can also be calculated on the basis of planning parameters instead of statistical parameters (i.e. anticipated prices expressed in foreign currency and domestic costs), in accordance with the principles

described above. For the reasons given below, the $E_k^r$ index represents an acceptable compromise between the requirements of theoretical correctness and of practical applicability. In the first place, it includes directional differentiation, and in large measure eliminates distortions arising from amortization allowances. Moreover, it is an index which provides a measure of the effectiveness of all domestic processing stages, except those in which actual alternatives of imports and exports exist. This deviation from the exact measure of direct and indirect labour costs towards actual alternative costs of exports and imports is correct from the point of view of rational decision-making in foreign trade; for what is essential is not the measurement of costs, but the taking of decisions which result in minimizing the costs to the economy as a whole. Finally, in common with all earlier indices, the $E_k^r$ index does not include scarcity levies, since these can be included only when the results of operational calculations for groups of interrelated activities have been obtained.

The use of the Effectiveness Indicator $E_k^r$ is common, as the balancing of foreign trade turnovers is centrally controlled. If the balance with a given market is too high, the Central Planner eliminates export items according to diminishing indices of $E_k^r$ (for a given $r$). If the balance with a given market is too low, the Central Planner includes in the plan further export items according to the growing index $E_k^r$; these items are selected in the first place from the items cancelled for other markets. If it is impossible to balance imports by means of available export commodities, the Central Planner achieves the balance by shifting imports. In practice,

the internal pressure for keeping imports is very strong (as well for investment needs, as for consumption goods), therefore, the last solution is highly disliked, and this results in a constant search for additional export possibilities. Once these new possibilities are discovered, one finds out that there are new additional requirements for imports. In this sense, one can state that in centrally planned economies, import needs are in practice "unlimited." As long as investment trends are allocated centrally by the State budget, there is no other constraint on import requirements by industrial sectors, than the discipline of the Central investment, and foreign trade plan.

A structural and directional allocation of this kind leads to the determination of balances at the required level, while a change of the structure leads to new structural and directional rates of exchange. With a list of $E_k^r$ indices for such an export plan to a given market, and knowing the results of the analysis of imports, the central planning authority corrects the initial values of the $M^r$ rates for the next plan period. Thus, frequent changes of the set of rates during the planning process can be avoided, and the optimization of the structure of the foreign trade plan takes place gradually over a longer period.

## 11.4. The Allocation of Funds for Investments Connected with Foreign Trade.

In the first stage of the application of the effectiveness analysis methods of comparative analysis of individual investment projects were introduced. The issues to be solved were:

-- which technique should be chosen to meet the production targets (final use effects) already established at the stage of plan formulation?

-- which investment project to choose in order to ensure an efficient choice of future foreign currency earnings (or savings)? Here the notion of "final use effect" is much broader than in the case of domestic comparisons; it admits not only choice among various techniques of production, but also among various investments in different sectors of the economy--provided they are directly linked with foreign trade.

The analysis of investment effectiveness consists in comparing all the use effects produced by the investment with total outlays of labour (i.e. investment outlays are compared with operating costs). The measurement of use effects and outlays poses many practical problems. There are as a rule great difficulties in measuring all use effects (direct and indirect) in the economy as a whole. In practice, there are very few cases where various alternative techniques ensure identical direct and indirect use effects. There are also great practical difficulties in measuring precisely investment outlays and operating costs, mainly on account of the inadequacy of the existing price system. Finally, there is the problem of arriving at effective proportions between different kinds of outlays and use effects, taking into account the macroeconomic requirements of development.

The actual stage of this evolution enlarges the sphere of choice based

on effectiveness criteria. The calculations are now being used not only to choose between projects representing different techniques while ensuring the same domestic use effect, but also to select the allocation of investments by sectors. A priority approach has been applied by creating five classes of investments, each class fulfilling definite requirements based on effectiveness indicators.

Investments influencing directly the balance of payment have reached the highest priority. The effectiveness criteria applied are deduced from the general model of optimization considering the existence of an investment fund devoted for the improvement of the balance of payments. The general criterion of optimization of fast recouperating investments connected with foreign trade runs as follows: 1/

$$\sum_{r} M^r D^r - (C + \alpha I) = \text{maximum},$$

where:

$M^r$ - marginal rate of market r ($r = 1, \ldots, s$),

$D^r$ - annual foreign currency balance of exports and imports for market r ($r = 1, \ldots, s$) at prices discounted according to delivery time,

$C$ - annual calculative production costs (materials at calculative prices) plus foreign trade costs,

$\alpha$ - marginal interest rate on supplementary investment,

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1/ See chapter 7 (Part II), and chapter 10.5 (Part III).

I - investment costs at calculative prices plus necessary turnover capital.

Hence the effectiveness index of investment connected with foreign trade takes the form

$$E_x = \frac{C + \alpha I}{\sum_r M^r D^r} \leq m_o < 1 .$$

The value of $m_o$ is differentiated for the above mentioned classes of investments. The values $M^r$ and $\alpha$ are fixed by the central planner. Foreign trade earnings and inputs are differentiated according to geographical destination or origin. An alternative formula reflecting the importance attached by the central planner to the necessity of earning quick foreign currency effects is used:

$$T = \frac{I_o}{\sum_r M^r D^r - C} \leq n_o$$

$$T_d = \frac{\sum_r M^r I_d^r}{\sum_r M^r D^r - C} \leq n_d ,$$

where:

$T$; $T_d$ - indexes of recoupment period,

$I_o$; $I_d$ - imported capital outlays,

$n_o$; $n_d$ - marginal recoupment period differentiated for various priority classes of investments and fixed by the central planner.

In addition to the above effectiveness indicators the following conditions have to be fulfilled to include investments to priority classes:

- the certitude of foreign demand (confirmed by foreign trade enterprises),
- the existence of qualified cadres,
- a minimum share of the total output devoted for export or substituting import,
- the certitude of supplies of raw materials based either on domestic supplies or granted by long-term agreements.

In practice both measurable and unmeasurable elements enter the analysis at various stages of investment planning.

## 12. The Practical Application of Systems of Indirect Management.

### 12.1. The Consecutive Systems.

As already mentioned, in order to achieve all the potential advantages of decentralization in a centrally planned economy, one has to remodel the motivational set up of decision-making. Effectiveness criteria must be connected with a system of incentives so as to promote the initiative of executive levels. Foreign trade must create the possibilities of comparing the domestic productivity with the level of productivity reached abroad and thus enable an objective evaluation of effectiveness among various enterprises and sectors. Prices, rates and profits so far passive instruments of aggregation and control are supposed to become active instruments of a rational allocation of resources. As already mentioned, all these elements of a system of indirect management of foreign trade are supposed to strengthen the basic

preferences of the central planner. These new categories are being introduced and tested within the traditional framework of the socialist economy. All this requires a successive stage-wise approach. These consecutive stages of the introduction of the new system of management are discussed in the next sections. First, a system of incentives based on a calculative effectiveness approach is explained. Second, an experimental system is shown, in which effectiveness criteria are integrated into the financial system. Third, the assumptions of the new pricing system are discussed. Finally, possible solutions of the new financial system are envisaged.

## 12.2. The First Complex System of Indirect Management: The Calculative Approach in Export Promotion.

Even in the most centralized model of a socialist economy there exist some spheres of activity where the decision-making power of the central planner is limited. Foreign trade is the sphere where these limitations are the strongest: foreign demand, foreign currency prices, quality requirements, terms of delivery, etc. are all conditions completely or partly independent from the central planner. In foreign trade decisions must be adapted to the changing situations which leave no time for sending reports to the central planner and for waiting for orders to come down through all intermediary levels of decision-making. Hence the necessity to decentralize decision-making in foreign trade. However, the important role of foreign trade in the creation of national income postulates not only decentralization but also rationalization of decision-making. The system of effectiveness analysis applied to planning was not sufficient to stimulate the initiative of executive levels

and had to be strengthened by a system of incentives. Hence in the middle of 1966 a new premium system based on the profit-maximizing criterion has been introduced and is still functioning. The application of this export effectiveness premium system has played a very important role in the preparation of further stages of a complex system of indirect management in the Polish economy. Hence it is worth while to discuss the export effectiveness premium system in more detail.

The foundations of the system were the following:

Premium (P) is being calculated as a function (f) of profit

$$\sum_r M^r D^r - C ,$$

i.e.

$$P = f\left(\sum_r M^r D^r - C\right) = \text{maximum} .$$

Hence the profit maximization criterion used as an instrument of rational allocation has been introduced for the first time in the socialist industry working for export.

The system was generally applied to the processing industries (raw-material industries were excluded as full centralized decision-making prevails there) and foreign trade enterprises. Associations of enterprises were not encompassed, as they were responsible for the determination of accounting prices, and hence indirectly the level of premiums.

The following problems were encountered.

First of all, the introduction of the profit criterion required adequate marginal rates and prices. The obligatory financial rates and prices actually

used were, for reasons already explained, completely inadequate as instruments of allocation of resources. Hence new calculative rates and shadow prices had to be determined and widely introduced. The problem has been much more complicated than the determination of shadow rates and effectiveness indicators used in the planning system, as shadow prices directly connected with premiums were susceptible of unobjective determination. Hence the necessity of connecting accounting prices directly with factory prices.

From the theoretical point of view the rates should be fixed at a marginal level. The first practical correction that had to be considered was that marginal magnitudes are constantly fluctuating, whereas central parameters being a calculative directive for thousands of enterprises could not be permanently changed. Therefore, a submarginal approach has been proposed. Stable rates were accepted, but some additional corrective systems were introduced. Finally, central parameters had to be determined on a level taking into account the existing resources and future possibilities of increasing exports and of improving their perspective structure. This has been, in essence, rather a guess than a factual analysis. A new important step has been made in the sphere of geographical differentiation of rates. As already mentioned in chapter 5 and 10, the following elements had to be taken into account while fixing the rates for the geographical allocation:

- differences in the commodity structure of foreign trade,
- differences in price levels in exports and imports,
- limitations in treaty obligations, payment conditions,
- foreign currency needs (repayment of debts, acquirement of loans).

A first attempt to take all these factors into account was made while determining directionally differentiated rates of foreign trade. The efficiency of this differentiation was confirmed by the results achieved. Faulty directional proportions had to be corrected in the course of the development of the system.

Still more complicated problems occurred with the determination of calculative prices. A two-level system of price determination has been created: the central level determined a price-list of basic raw materials (using world prices multiplied by rates), and these in turn were used at the level of inductrial associations to compute calculative indexes for individual commodities. These corrective coefficients to domestic price lists were then formally settled and madeobligatory in the premium calculations. These price lists were a first approximation of accounting (shadow prices and formed a first practical attempt to create a new overall system of prices adapted to the requirements of rational allocation calculus.

The function (f) in terms of a fixed percentage rate has been determined equal for all sectors. The transition from a system where there exist no connections between effects and earnings to a system with a rigid relationship between profit and worker's earnings created a danger of drastic discrepancies in earnings, affecting social justice (e.g. earnings in ultramodern establishments equipped by the State versus earnings in factories with obsolete labour-intensive processes) or the danger of placing all possible consequences of external factors on the workers (e.g. fluctuations of foreign prices or the cancellation of State orders). The impact of these new principles on the

attitude of socialist enterprises was very strong. The following ways of escaping from the danger of great discrepancies in earnings were envisaged:

- determining upper ceilings of premiums in terms of monthly salaries,
- differentiation of the percentage rate for specific branches or enterprises,
- the introduction of the rate of interest on capital,
- the acceptance of profit increase instead of profit as a base for premiums,
- the introduction of a progressive tax system.

Due to the lack of adequate knowledge of potential resources of profit increases in various enterprises, the first solution, as the simplest, has been chosen. This means, however, that the correct working of the system is restricted to the limits settled by the ceilings.

The new system brought an important contribution: it has created new economic ties between productive and foreign trade enterprises. Up until now attempts have been made to delimit as strictly as possible the responsibilities of the producers from those of the foreign trade enterprises. In practice, it did not work and it created many conflicts, as these responsibilites are closely interconnected. In the new system, a different solution has been accepted. As both partners are contributing to the results in exports, the identical basis for incentives has been determined for both: the producer and the exporter. This has created new economic ties between both partners.

## 12.3. The POLFA Experiment - The Integration of the Calculative System with the Financial System.

The main deficiency of the system of export incentives is the calculative character of the profit maximization criterion. There is no direct connection between the calculative system of effectiveness accounting and the financial system. To overcome this deficiency and to assess the possibilities of connecting the two systems, an economic experiment in the pharmaceutical industry working for export has been introduced in parallel with the general calculative system of export effectiveness incentives. The characteristic feature differentiating this experimental system from the general system of export effectiveness premiums are the following:

- accounting (effectiveness) prices became obligatory prices; to do this a system of special "raw material taxes" or "subsidies" has been introduced. These are a financial instrument of correction of the obligatory pricing system and are aimed at rationalizing the allocative choices. The computational rules of the "taxes" or "subsidies" result directly from shadow pricing principles;
- the directionally differentiated marginal rates became financial rates of exchange, applied by the banking system for the experimenting branch;
- the subject of the experiment is the industrial association, which divides the acquired profits and premiums among its enterprises. This principle increases the role of the association, which becomes a powerful centre of decision-making;

- the experimental system encompasses the global results of foreign trade activities, i.e. not only profits from exports, but also profits from imports. Lower prices paid for imported raw materials or savings on quantities of imported material used in the productive processes result directly in export profit increases for both: the producer and the foreign trade enterprise;
- to connect both systems--effectiveness and the financial--special taxing rules have been introduced. More specifically, a special export tax is levied by the Stage Budget to compensate the increased financial means accruing from the use of uniform exchange rates (i.e. the difference between the submarginal rate and the mean financial indicator of foreign trade). This tax has been determined in the form of a fixed amount, which means that the criterion of profit has been replaced by the criterion of profit increase;
- similarly to the general export effectiveness premium system, the experimental POLFA system left unchanged the internal prices for the domestic products. Hence the system does not influence the domestic production, which is determined by traditional plan directives. 1/

The POLFA experiment has been assessed as the best experiment introduced in Poland. The results achieved were spectacular. These results proved that there exist important reserves in the productivity of labour, and that these reserves can be shown if an adequate system of management is applied. It became apparent that the maintenance of stable normatives relating profits

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1/ This has been recently changed by enlarging the principles of shadow pricing also to domestic production and integrating profits from export production with profits from domestic production. However, this change affected only prices for producers and not for consumers.

and premiums requires the introduction of a progressive income tax.

12.4. The Reform of Prices.

The general assumption of the price reform was the connection of the price system with the criteria of economic calculus. To evaluate the pricing reform, let us recapitulate the principles of price formation resulting from the analysis of the properties of the optimal solution of the model presented in chapters 6 and 11.

The following relationships occur in the optimal solution between shadow prices ($l_k$), scarcity rents due to production limitations ($G_k$), scarcity rents due to limitation of foreign demand for exports on market r ($N_k^{Er}$) and limitations of foreign supply for imports ($N_k^{Ir}$), processing costs ($c_k$), input-output technological coefficients ($a_{jk}$), foreign currency prices in exports ($d_k^{Er}$) and in imports ($d_k^{Ir}$):

a) for the production (assuming a single technology for a product)

$$l_k = \sum_j a_{jk} l_j + c_k + G_k,$$

b) for exports

$$l_k = M^r d_k^{Er} - N_k^{Er},$$

c) for imports

$$l_k = M^r d_k^{Ir} + N_k^{Ir}.$$

If we pass from the model of current optimization, assuming the constancy of productive capacities to a model taking into account investment possibilities, we get the relationship between scarcity rents due to productive capacity limitations ($G_k$) with the marginal interest rate of investment ($\alpha$) necessary to create these productive capacities. If past investment decisions were optimal, then:

$$G_k \geq \alpha I_k ,$$

where:

$\alpha$ - the marginal interest rate (or the marginal profit rate),

$I_k$ - yearly investment outlay per unit of productive capacity.

Hence, knowing foreign currency prices, marginal rates, the marginal interest rate, investment outlays and internal and external limitations we can determine the approximate values of prices. These theoretical assumptions and conditions are very difficult to be met in practice. Two kinds of difficulties occur.

First, there are problems connected with the information system. It is not easy to get information concerning the foreign trade prices. Foreign trade prices are different, they are fluctuating, they depend upon quantities purchased or sold, they depend upon the quality of commodities purchased or sold, they depend upon the quality of commodities traded, etc. Foreign demand possibilities--affecting the calculative price $1_k$ --are even more difficult to be analysed. The same applies to foreign supply, especially one connected with bilateral agreements, where the supply of some commodities may depend upon the demand for other commodities. Still accepting some

simplifying assumptions it is possible to derive accounting prices from foreign trade data. However, the situation is much more complex with detailed information concerning the technical coefficients, productive capacities, processing costs, investment outlays, domestic demand, etc. as the solution of the equilibrium price has to be determined by mathematical methods. Here we come to the second difficulty, namely, the computing limitations. These difficulties are possible to be overcome in some branches which can be tackled with existing computing possibilities. But the majority of domestic activities which are interrelated with many other sectors, cannot be solved with the help of computers, at least in the actual state of affairs. Therefore, the following basic principles were formulated as a general directive for price setting authorities:

- raw-materials, materials and goods being actually traded with abroad (i.e. exportable or importable goods) are fixed on the basis of world prices. As fluctuations of these prices would create difficult problems in domestic pricing of finished products--prices of raw materials are based on expected long-term world prices--and fixed for a longer period of time. Revisions of these prices will occur in cases, where the actual developments in world prices would differ essentially from the projected level;
- other (non-basic) imported commodities are priced according to their foreign prices multiplied by foreign trade uniform multipliers;
- domestic finished products are based on costs (including investment interest rate) plus normative profits. However, also

in this group of commodities drastic discrepancies with world prices are not tolerated and a special pricing policy aimed at changing such prices is foreseen.

These new wholesale prices for productive uses were worked out for two years and have been introduced starting from January 1, 1971. As can be seen the new rules of price formation are an important step towards diminishing the gap which existed until now between domestic and world prices. These new prices may be better suited for a more rational allocation of resources. They create a prerequisite for the introduction of a new complex financial system.

As already mentioned, there are two basic problems connected with the further functioning of a price-system:

- the real possibility of the Central Planner in performing effective control over pricing at various levels of decision-making, this problem is especially relevant for non-tradables, produced by monopolistic manufacturers and based hiterto on cost-plus basis
- frequency of changes in obligatory prices due to the changes of actual shadow prices.

It is too early to evaluate the performance of the new price system introduced recently. Its ability to cope with these problems remains to be seen.

## 13. Tentative Conclusions for Further Applications.

### 13.1. The Possible Variants of the Financial System.

There are various possible forms of relating the analysis of economic effectiveness to the financial system.

Depending upon the forms of these relations we distinguish two basic types of the financial system: the effectiveness one, i.e. the one consistent with the postulates of the analysis of effectiveness, and the non-effectiveness one, which does not satisfy this postulate.

From the point of view of relationships between the financial system and the incentive system we distinguish the financial systems which are incentive-active and incentive-passive.

From the four possible types of the financial system: the effectiveness type incentive-active, the effectiveness type incentive-passive, the non-effectiveness incentive-passive, and the non-effectiveness incentive-active, the fourth type, i.e. the non-effectiveness incentive-active is, of course, inacceptable. 1/

In the non-effectiveness system the accounting prices, as an instrument of the analysis of effectiveness, are not related to the prices of the financial system, similarly as the calculative profit has no relation with the financial balance-sheet profit. If, however, the financial system takes over the functions of the effectiveness system, then it can be related to the incentive system thus making of it an effectiveness system of the incentive-active type. In the further parts of this section, we shall look at expected probable developments of the management system--from the angle of the above mentioned criteria.

It is quite difficult to apply a uniform and incentive-active system of management in existing conditions of a centrally planned economy. The category of "normative" profit included in the factory price differs obviously

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1/ Though there exist many proponents of that solution in practice.

from the category of profit, which results as a difference between parametric prices and costs. The first can be "negotiated" with price setting authorities and "manipulated" so as to contain monopolistic rents. In these conditions there is the danger that profit maximization may lead to price increases instead of lowering of costs. On the contrary, profit maximization measured at objective parametric prices leads to positive results: better prices reached in exports, lower prices paid for imports, lower costs and a better commodity structure. As long as there exists a monopolistic structure of production (industrial branch associations are perfect monopolies) and as long as there exist no pricing rules that could eliminate the danger of monopolistic rents, it seems that different types of management systems will function: the effectiveness incentive-active in the spheres where parametric prices exist, and the non-effectiveness incentive-passive in the rest of the economy.

The connection of the financial system with effectiveness depends on prices, and here it is difficult to show a strict division line between parametric effectiveness and non-parametric unobjective prices.

The main difference will be the system of incentives applied. In these spheres where the incentive-active system is applied, premiums are a growing function of profits. In the remaining spheres, the connection between financial effects and premiums are loose and assumed ex ante premium ceilings restrict their growth.

The formal financial framework may be uniform for both systems of management. However, it may be differentiated depending upon the organizational structure of the connections between the producer and the exporter. These

organizational forms require some explanations. The general tendency is towards creating direct ties between the domestic and the foreign market. Although the economic ties are evidently the most important there exists also a tendency to pull down the barricade of organizational difficulties and to enable producers to get in direct touch with markets abroad and to compare directly their productivity with that of other countries.

The organizational principles of the monopoly of foreign trade are well known and need no clarification. Foreign trade transactions were made exclusively on the own account of the foreign trade enterprise. But this was a formal point of view. In reality, the functioning of the system of budget differentials accepted all possible financial gains or losses. Hence in reality foreign trade enterprises had no financial responsibility whatsoever. All financial consequences were taken over by the State Budget. The new directives diminish the share of transactions made on the own account of foreign trade enterprises. The form of a commission-agent of a producer has been generally accepted as the basic organizational form of a foreign trade enterprise. This commission-agent is interested in achieving a surplus above (or--in import--below) the price limited by the producer. Alternatively both, the producer and the foreign trade enterprise, share in the same profits, in fixed proportions. This change is quite important and brings about the direct interest of producers in achieving the best foreign trade results: highest export prices, lowest domestic costs and best commodity structure of the export.

A certain number of productive enterprises were given the right to export and import directly. Initially, this number has been restricted, but

it may be gradually increased in the future. A stage-wise approach has been also accepted in connecting producers' and foreign trade activities: preparatory functions for export, preparatory technical consultations, common purchases, finally independent trading by producers, these are all consecutive stages of this process.

It is difficult to discuss the characteristic features of the future management system in the stage of its construction, when many questions are still open. Therefore, only a very general analysis of the theoretically possible and probable solutions of the financial system and of the incentive system can be presented. In general, it is probable that elements of direct management--as already explained--will be limited and elements of indirect management broadened.

The amount of obligatory plan indicators will be reduced leaving more space for decision-making within the framework of both: the financial and the incentive systems. It is generally assumed, that uniform foreign trade rates (multipliers) will be introduced as well in the planning, as in the banking system. These rates will be probably differentiated for the basic geographical and payment groups. Assuming that the foreign trade multipliers will probably be based rather on mean than on marginal values, a corrective system of taxes and subsidies will have to be introduced.

It may be necessary to apply export and import licenses, to give the Ministry of Foreign Trade an instrument of preventing control, yielding information about the intentions of exporters and importers as to the commodity pattern and geographical directions of exports and imports.

The anticipated system of subsidies provides a possibility to adapt the structure of exports to new requirements, thus eliminating seccessively the ineffective exports, modernizing production and improving export prices reached. The system is aimed at securing a transition from the initial stage of complete separation of the producers from abroad to new conditions in which a closer connection with foreign markets will exercise a more decisive influence on the behaviour of producers and exporters. These subsidies are intended to cover export losses for industrial associations as a whole and not for individual commodities. The associations may then redistribute the funds received among individual productive enterprises. The rate of the subsidy will probably be calculated in such a way so as to include a margin for a normative profit, similar to the profit reached in the domestic production. The system of special refunds must be envisaged for covering eventual losses connected with the realization of interstate long-term agreements. In industries where subsidizing will be applied a tendency towards a material-intensive export may occur. To counteract these tendencies, raw material taxes or customs duties may be used.

It seems probable that the system of incentives may be differentiated for those enterprises whose export share is high and hence prices can be regarded as parametric, and the remaining exporting industires, where the production for export does not enable the evaluation of the total production in parametric prices.

In the first group of enterprises, the whole production--the exported as well as the domestic--can be priced in parametric prices, proportional

to foreign trade prices. Profits as the difference between prices and costs may be fully integrated: those from export with those from domestic production. Incentives may be directly linked with the profit maximizing criterion and there is no necessity of introducing premium-ceilings, but rather a progressive income taxation.

In the second much broader group of enterprises, profits will only be partially integrated. The export profit will be the difference between the export currency price multiplied by foreign trade multipliers and the factory price. The domesticprofits will be the difference between the factory price and costs. Incentives for exports will be integrated with incentives for domestic production, and hence they have to be limited. The probably important assumption is, that--contrary to the domestic systems used so far--incentives will not be related to plan fulfilment indices, but to the improvement of the indexes of the base period. This may lead to the avoidance of the plan bargaining procedures as well as of reserve hiding tendencies.

The basic dilemma, how to integrate incentives for exports with those for the domestic production and whether to rely on overall economic criteria (profit measured in non-parametric prices) or on partial technological indicators, cannot be easily solved in conditions where no competition among enterprises exists.

The traditional system of financing investments according to the overall plan will probably be supplemented by a general fund for fast recouperating investments connected with foreign trade. These investments may be financed from credits obtained from the foreign trade bank and may be repaid from current profits. The credit system for foreign trade investments will select from the investment

proposals available only the best ones in accordance to the profit maximizing criterion. Hence enterprises will have to compete with each other observing the minimum effectiveness requirements.

The transition from a system of direct management, in which internal prices and profits are completely separated from external influences, to a system of mixed: direct and indirect management, in which the domestic and the foreign market are closely linked, must face several difficult problems and must have a strong impact upon the attitude of industry towards foreign trade. It is a deep change to pass over from the budget differentials account, which supplied the productive enterprises with financial means according to the criterion of "need," whatever those financial results were, to a system of foreign trade multipliers, subsidies and taxes, which compells the industrial units to draw their attention to the results achieved in foreign trade. Economic considerations assume new importance and influence directly the level of premiums. New prices--although far from being perfect--are becoming an instrument of resource allocation, a completely new function for the passive pricing system. The evolution from bargaining for investment funds received free of charge from the State Budget to a system of credits for foreign trade investments, evaluated by the bank on the basis of economic criteria and facing competition, shows the far-reaching consequences of all these changes. It shows also that all these changes cannot be implemented at once, but require a stage-wise approach connected not only with the construction of new instruments of the indirect management system, but also with a deep change of attitude of the cadres implementing these reforms.

13.2. Problems of Further Possible Applications.

It is not the task of this section to summarize all the conclusions of the former chapters. Here we shall rather point out some of the problems one faces when one wants to improve the management system in practice.

The first basic impression is the discovery of a gap that exists in the state of knowledge on the system of efficient planning and management in a centrally planned economy. There exists no theoretical model of dynamic multi-level decision-making in long- and medium-term planning that could be treated as a basis for management system. Here, one can agree with the general criticism of J. Kornai [1/] dealing with the models of the General Equilibrium Theory. The possible deficiencies of the models' assumptions in respect to reality are:

- the static /or stationary/ character,
- the constancy of the set of organizations over time,
- the lack of distinguishing the multi-level character of decision-making in a real planned economy by focussing the attention only to producers and consumers,
- the constancy of the set of products,
- the simultaneous character of different activities (the lack of consideration of time lags between production-sale-consumption),

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[1/] J. Kornai: Anti-Equilibrium, (To Be Published).

- the convexity of the production set, resulting in the negligence of the existence of: indivisible products and resources, discontinuities, increasing returns to scale, increasing marginal rate of substitution between factors of production,
- profit maximization as a concave function,
- maximization of consumers utility relying on the assumption that the set of possible consumption is convex, and that the consumer has a preference ordering over this set,
- the constancy of production and consumption sets and of preference ordering,
- exclusivity of price information flows,
- anonymity of market relations,
- lack of uncertainty.

These potential deviations of Model Assumptions from reality are harmful in the long- and medium-term planning. However, they are certainly much less harmful in the short run. Hence, while one can delimit large spheres of short run decision-making where the assumptions of the optimization models described in Part II hold in reality, nevertheless one has to be concious of their limited applicability to the long-run. Therefore, the first possible criticism of our analysis may point at the weak links between the short and the long-run, i.e. the mutual relationship between longer term plans and short-run management. The second difficult problem that arises from the limited sphere of permissible application of our model assumptions is the coexistence of different models of decision-making in reality, as described in chapter 1.

Unfortunately, the theory of coexistence of mixed models is rather poor; nevertheless, it is not possible to disregard reality and to object to the existence of monopolies, oligopolies, increasing returns to scale and uncertainties in some sectors where these features are characteristic and not exceptional. For the time being we do not see any better practical solution than the pragmatic division of the economy into two separate spheres: the one where the assumptions of our model analysis hold, and the other where the command system has to remain. Being fully aware of these difficulties, we are convinced that there are vast shperes of economic activity where the application of an indirect system of management based on the principles described is fully justified. In a country where the share of foreign trade (tradeables) is high, and will certainly be growing, the possibilities of enlarging the sphere of indirect management are very considerable. The recent developments in formulating algorithms [1/] enabling the determination of equilibrium prices creates further prospects for the application of mechanisms of indirect management in those additional spheres where the inputs and outputs are stable and measureable and where the central control of prices may prove effective.

The introduction of optimization models into practice has led to many sharp conflicts. The logic of the incentive-active, and effectiveness oriented new system of indirect management in foreign trade did not conform to the incentive-passive and non-effectiveness oriented domestic system of prices. Parametric prices enabled the use of profit maximizing criterion

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[1/] H. Scarf, "On the Computation of Equilibrium Prices," Cowles Foundation Papers, No. 271.

connected with financial stimuli. "Cost Plus" prices with decreed profits were aimed at a full neutralization of preferences of executive levels as to the choice of product-mix. As both systems were simultaneously operating in the same enterprises, they created internal conflicts. The incentive-active approach, connected with the stimulation of improvements in relation to the objective base period conflicted with the yearly plan-fulfillment approach: the first was basically oriented to stimulate initiative and to release all existing reserves from below, the second assumed the knowledge of the center as to the magnitude of potential reserves at the executive level. For the first time in the centrally planned economy, the new system led to spontaneous requests from below to decrease domestic prices in order to increase foreign trade profits, as the old system favoured domestic price increases.

Finally, there occured conflicts between the central plan and the functioning of the indirect mechanism in all these cases, where the central parameters have been fixed at wrong levels. It is needless to say how dangerous such conflicts may be for the smooth functioning of decision-making in a centrally planned economy. It is thus necessary that the central parameters be constantly controlled and adapted to the changing conditions. It is also necessary that the system of decision-making be adapted to the particular sphere of economic activity.

The construction of new, improved rules of indirect management require a consistent model analysis of the system. There is no more sense of applying partial criteria, mutually inconsistent where there are real possibilities of deriving general rules from over-all models. Of course, this

requires a formulation of basic guidelines from policy makers as to the political and social preferences. Hence, the most general conclusion that can be derived from the Polish experiences with the application of mechanisms of indirect management is the usefulness of the non-numerical model analysis to the derivation of rules of the functioning of the management system. Only this approach can ensure the mutual consistency of criteria used and of the internal logic of decision-making. To preserve this logic in the current functioning of a centrally planned economy, the improvement of the management system must become a constant preoccupation of the policy maker in close cooperation with model-builders.

One would be tempted to possess, at least in theory, decomposition algorithms that would ensure that each iterative step be feasible, that it be monotonically improving the value of the preference function, that it be not motivationally disturbed by partial preferences of executive levels, that it would have a low informational cost and low computational burden. However, waiting for the discovery of such an algorithm would mean the postponement of reforms of the management system for an indeterminate period of time. Therefore, the pragmatic approach applied in the Polish experiments using the statistical determination of central parameters and the use of the traditional planning apparatus as a substitute for an electronic computer, seems to be, at least for the time being, a second best solution. Of course, the search for more satisfactory solutions should continue.

Another practical conclusion deals with the great importance of the intuitive "Expert value judgement" at the central, as well as at the executive level of decision-making. It is important in cases where reality

is too complicated to be dealt with, with over-all models, e.g. the determination of central parameters $M^r$ and $K^r$ by experts, taking into account tie-in-sale treaty requirements, or expected repercussions of current changes in the balance of payment situations. It is equally important in simple cases, where the sole introduction of the profit maximizing criterion helps in the selection of effective variants by the expert enterprise planner, without the formal use of operations research techniques.

There were many theoretical discussions in Poland at a very competent intellectual level, especially those within the framework of the Economic Council presided by O. Lange in the 1957-58 period. However, these theoretical considerations have had no practical follow up. On the other hand, there were many partial economic experiments in the period of the early sixties, but these experiments were lacking any underlying over-all unifying theoretical basis. In both periods, there was no cooperation between policy makers and model-builders. On the contrary, the consecutive steps in the application of the optimization models in foreign trade were based on an over-all theoretical approach, which enabled a consequent enlargement of the system from an analytical into a decisional one, and from a restricted foreign trade model into an macro-short-run decision-making model, encompassing conceptually the over-all economy, and practically very broad sectors. Though this process was full of conflicts, difficulties and problems, it proved to be successful. Hence, the conclusion that successful changes of management systems requires a closest cooperation of policy makers, model-builders, and practical planners. Without creating conditions for such a cooperation,

there are no chances for successful implementations. Policy-makers have usually a low preference for the preservation of internal consistency of any pure system. They usually also dislike to be committed by any goals and choice of underlying assumptions that would then be binding. Model-builders have usually an instinctive fear from being involved into down-to-earth practical "technicalities." They also dislike to work under a constant pressure of time limits and stress from the other two groups. Practical managers and administrators highly dislike being directed and taught by the other partners. They usually show little understanding for general principles that result from over-all systems' requirements. It is not an easy task to confront the three groups in a complex team with their low propensities to commitments, responsibility and principles respectively; however, without it there are no real chances for success.

The complex elaboration and application of economic changes in the system of management does not mean that only integral over-all reforms are the best practical solution. Changes may be introduced partially with more cautiousness and less risks than total reforms with no ex-ante knowledge about all the possible consequences of the "jump into the unknown," However, these changes must be feasible and internally consistent. They must encompass all the interrelated activities simultaneously and take into account the logic of the sequence in time. Therefore, it seems that the over-all strategy of the changes should be worked out in advance and in a complex way while the implementation may be partial and stage-wise.

13.3. Further Research.

The social responsibility of model-builders engaged in the improvement of decision-making systems working in reality is very high. The list of unanswered questions is very long. The construction of models based on realistic assumptions, more closely related to the reality of a centrally planned economy. The integration of monopolistic or oligopolistic sectors with the competitive sectors. If this proves impossible, the formulation of rules for the coexistence of mixed systems of decision-making. Markets with free prices versus markets with decreeted prices. The delimitation of spheres of economic activity for different types of decision-making systems. The use of central parameters and the techniques of their determination. The development of algorithms that could fulfill the requirements of monotonic and speedy convergence, working at low informational costs and low computational burden.

The list of problems and unanswered questions may be prolonged indefinitely. It seems, that the newly discovered demand in Socialist countries for answering these questions will stimulate adequate supply. It is obvious that much can be gained by a comparative approach of different decision-making systems. As the elaboration of new models takes time, important improvements could be gained by the promotion of exchanges of ideas and experiences between various scientific centers working on the subject.

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