POLISH ACADEMY OF SCIENCES
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Warszawa 1992

PREFACE

The main difference between the work here presented and the other studies related to the same, generally speaking, domain, consists in the fact that considerations contained in this book indicate the possibility of resolving questions concerning the choice of the subject and establishment of profitability of international trade and cooperation in conditions when:

* prices on the internal market do not correspond to social costs,

* there is lack of conviction as to correctness of exchange rates,

* prices in international trade are subject to manipulations, resulting from definite interests of some countries, or they simply cannot follow the development of world production system.

As can easily be noticed these are just the conditions in which currently the international trade and cooperation system is being shaped. These particular conditions result, for instance, from governmental subsidies oriented at individual commodities or groups of commodities (e.g. food products), from existing custom tax barriers and from an extremely quick pace of technological progress in the techniques of production.

INTRODUCTION

The problem of international exchange was presented for the first time in precise mathematical terms by Wassily Leontief in his paper entitled "Factor Proportions and the Structure of American Trade", published in *Review of Economics and Statistics* (1956, vol. 38, no. 4).

The first mathematical approach to the problem presented in Poland, was of international industrial cooperation formulated in the Doctoral dissertation of Andrzej Ameljańczyk (Military Technical Academy, 1975), supervised by this author.

Earlier, a similar formulation of the problem of international trade exchange had been forwarded in the Doctoral dissertation of J.Kotyński (Main School of Planning and Statistics, Warsaw, 1968).

If we distinquish the specific problem of international economic cooperation within the broader domain of international trade exchange then the first monograph devoted entirely to economic cooperation is the book in Polish by S.Piasecki, J.Hołuniec and A.Ameljańczyk, entitled "International economic cooperation - Modelling and Optimization" (PWN, Warsaw-Łódź, 1982).

The assumption of complementarity of goods, characteristic for the problem of cooperation, was first introduced by D.Graham in 1923 in his paper "The Theory of International Values Examined" (Quarterly Journal of Economics, vol. 38, no.1).

The present publication contains the original results of studies conducted during the years 1982-1985, being a continuation of work started a dozen years before.

Models of international cooperation considered there (see Chapters 1 to 3) were much simpler than in the ones presented here. Still, they are, alas, only theoretical models, which cannot be practically applied in economic activity.

Notwithstanding this situation, the models give certain possibilities with respect to applications. I am convinced that

further in-depth studies in and broadening of the theory presented here will make out of it in the future a perfect instrument for economic practice. I think that conclusions resulting from it may contribute to quicker reequilibration of the international economic system, which has been put so much off the equilibrium by the existing debts.

Against the background of existing numerous publications dealing with international trade and cooperation, as well as international specialization, the theory here presented does not require acceptance of the commonly up to date adopted assumption concerning economic equilibria within the cooperating countries, and, furthermore, this theory has much greater practical potential than the previous theories, in which it has been necessary to assume existence of economic equilibrium prices for comparing profitability of trade.

Since the theory presented in this book is independent of existence of prices, it can also be used in determination of the price structure of goods included in the trade, profitable for the partners in such an international trade deal. Thus, the structure determined ("terms of trade") guarantees stimulation of international cooperation and improvement of international specialization.

On the other hand, the theory can also be used in deciding whether the structure of prices actually existing in the international market is enhancing or, to the contrary, hindering, the development of trade, whether it does not lead to an unsound development of some of the partners at the expense of the other ones. It is not difficult to realize that the theory presented, and especially its results, concern one of the essential economic problems of present time.

The theory has, indeed, its weak points as well. A number of technical simplifying assumptions put aside (their number shall be decreasing as the theory develops), there is one fundamental assumption. It says that every participant of cooperation relation (of international trade) tries to produce the maximum of necessary goods of a given structure, entering the group

considered.

When these ones are consumption goods, we are dealing with the situation, when every partner (every national economy) participating in international exchange, is geared towards maximization of the living standard of own population, given a consumption structure characteristic for this population.

When, however, these are not consumption goods, but, e.g. semi-products, then this corresponds to the situation in which every participant-producer tries to maximize own production, this production determining the structure of demand for semi-products encompassed by cooperation. From this point of view the theory presented may get applied beyond the domain of international cooperation.

Technical simplifications adopted in the book result from the wish of possibly clear and understandable presentation of the theory. Thus, wanting to show graphically the mechanism of cooperation and to illustrate the results of the theory, the present author emphasizes in the book bilateral cooperation encompassing only two kinds or groups of commodities. Analysis of the thus simplified problem is contained in first seven chapters of the book.

The eighth chapter is in a way a generalization of considerations presented in the previous chapters so as to account for the case of multilateral cooperation, involving multiple goods. This chapter may constitute a separate whole - a summary of the contents of the book.

6. THE CHOICE OF COOPERATION RELATIONS

Let us prove at the outset the theorem of the following contents:

Theorem 3:

If it is true that

$$\frac{1 + b_{21}^{I} \cdot \frac{A_2^{I}}{A_1^{I}}}{1 + b_{21}^{II} \cdot \frac{A_2^{II}}{A_1^{II}}} = \frac{b_{12}^{I} + \frac{A_2^{I}}{A_1^{I}}}{b_{12}^{II} + \frac{A_2^{I}}{A_1^{I}}}$$

then the overall consumption $\beta_1, \beta_2 = \gamma_2\beta_1$ is equal

$$\overset{*}{\beta}_1 = \frac{B_{21}^{II}}{B^{II}} \cdot D - G = \frac{B_{21}^{I}}{B^{I}} \cdot D - G = \overset{\odot I}{\beta}_1 + \overset{\odot II}{\beta}_1$$

(where $\overset{\odot I}{\beta}_1, \overset{\odot II}{\beta}_1$ are consumption magnitudes which each of the sides can assure for itself irrespective of cooperation) and it does not depend upon the choice of extremum production strategies $(\alpha_1^{I}, \alpha_1^{II})$ and $(\alpha_2^{I}, \alpha_2^{II})$, that is - the ones which satisfy conditions

$$\frac{\alpha_1^{I}}{A_1^{I}} + \frac{\alpha_2^{I}}{A_2^{I}} = 1$$

$$\frac{\alpha_1^{II}}{A_1^{II}} + \frac{\alpha_2^{II}}{A_2^{II}} = 1$$

Proof.

Take any pair of feasible extremum strategies, $(\alpha_1^I, \alpha_1^{II})$, that is - the ones which satisfy the two inequalities given before, and such that guarantee balancing of exchange, i.e.

$$\mu_1^I + \mu_1^{II} = 0$$

$$\mu_2^I + \mu_2^{II} = 0$$

with the given consumption structure

$$\frac{\beta_2^I}{\beta_1^I} = \frac{\beta_2^{II}}{\beta_1^{II}} = \gamma_2$$

As we know from our previous considerations, resulting from the solution of the three mentioned systems of equations is the relations

$$\alpha_1^I B^I + \alpha_1^{II} B^{II} + D$$

By making use of the assumptions of the Theorem and denoting

$$\phi = \frac{B_{21}^I}{B_{21}^{II}} = \frac{B_{12}^I}{B_{12}^{II}}$$

we obtain

$$B^I = B_{21}^I + \frac{1}{\gamma_2} \cdot B_{12}^I = \phi B_{21}^{II} + \frac{1}{\gamma_2} \cdot \phi B_{12}^{II} = \phi B^{II}$$

Therefrom the relation between α_1^I and α_1^{II} can be written down in the form

$$\alpha_1^I \phi + \alpha_1^{II} = \frac{D}{B^{II}}$$

On the other hand (see p.) for the extremum feasible strategies we have relation

$$\alpha_1^I B_{21}^I + \alpha_1^{II} B_{21}^{II} = G + \beta_1$$

where $\beta_1 = \beta_1^I + \beta_1^{II}$. Therefrom, having replaced B_{21}^I with $B_{21}^I \phi$ we obtain:

$$\alpha_1^I \phi + \alpha_1^{II} = \frac{G + \beta_1}{B_{21}^{II}}$$

Comparing the left hand sides of the relations obtained we see that they are identical, so that the right hand sides must also be equal:

$$\frac{D}{B^{II}} = \frac{G + \beta_1}{B_{21}^{II}}$$

and finally

$$\beta_1 = \frac{D}{B^{II}} \cdot B_{21}^{II} - G$$

or, after substitution of $B^{II} = \frac{1}{\phi} \cdot B^I$, $\quad B_{21}^{II} = \frac{1}{\phi} \cdot B_{21}^I$,

$$\beta_1 = \frac{D}{B^I} \cdot B_{21}^I - G$$

Thus, we have demonstrated that β_1 does not, in fact, depend upon the adopted strategy $(\alpha_1^I, \alpha_1^{II})$ if the latter is extremal (and, of course, it satisfies the conditions resulting from the consumption structure and the necessity of balancing the cooperation exchange). Simultaneously, the value of β_1 is in such a case as given in the proposition of the Theorem. In order to complete the proof we should demonstrate yet that

$$\beta_1 = \frac{B_{21}^{II}}{B^{II}} D - G$$

where: $\overset{\odot}{\beta}_1 = \overset{\odot I}{\beta}_1 + \overset{\odot II}{\beta}_1$ and $\overset{\odot}{\beta}_2 = \overset{\odot I}{\beta}_2 + \overset{\odot II}{\beta}_2 = \gamma_2\overset{\odot}{\beta}_1$ is the overall consumption of both sides in case of lack of cooperation, that means - when each side maximizes own consumption independently. As we know (see p. 3) - in case of autarchic economy each side can at most reach the following levels of consumption:

$$\overset{\odot I}{\beta}_1 = \frac{A_2^I(1 - b_{12}^I b_{21}^I)}{\gamma_2 B^I}, \qquad \overset{\odot I}{\beta}_2 = \gamma_2\overset{\odot I}{\beta}_1$$

$$\overset{\odot II}{\beta}_1 = \frac{A_2^{II}(1 - b_{12}^{II} b_{21}^{II})}{\gamma_2 B^I}, \qquad \overset{\odot II}{\beta}_2 = \gamma_2\overset{\odot II}{\beta}_1$$

under the production strategies, respectively:

$$\overset{\odot I}{\alpha}_1 = \frac{A_1^I(1 + \gamma_2 b_{21}^I)}{\gamma_2 B^I}, \qquad \overset{\odot I}{\alpha}_2 = A_2^I - \overset{\odot I}{\alpha}_1 \cdot \frac{A_2^I}{A_1^I}$$

$$\overset{\odot II}{\alpha}_1 = \frac{A_2^{II}(1 + \gamma_2 b_{21}^{II})}{\gamma_2 B^{II}}, \qquad \overset{\odot II}{\alpha}_2 = A_2^{II} - \overset{\odot II}{\alpha}_1 \cdot \frac{A_2^{II}}{A_1^{II}}$$

As can easily be verified the pair of strategies $(\overset{\odot I}{\alpha}_1, \overset{\odot II}{\alpha}_1)$ satisfies the relation

$$\overset{\odot I}{\alpha}_1 \phi + \overset{\odot II}{\alpha}_1 = \frac{D}{B^{II}}$$

since

$$\frac{\phi A_2^I(1 + \gamma_2 b_{21}^I)}{\phi \gamma_2 B^{II}} + \frac{A_2^{II}(1 + \gamma_2 b_{21}^{II})}{\gamma_2 B^{II}} = \frac{\frac{1}{\gamma_2}(A_2^I + A_2^{II}) + A_2^I b_{21}^I + A_2^{II} b_{21}^{II}}{B^{II}}$$

This pair fulfill also the second relation:

$$\overset{\odot}{\alpha}{}_1^{I}\phi + \overset{\odot}{\alpha}{}_1^{II} = \frac{G + \overset{\odot}{\beta}_1}{B^{II}}$$

which it is somewhat more difficult to demonstrate via formal algebraic transformations, but which can be proved in the following way:

Thus, namely, the pair of strategies $(\overset{\odot}{\alpha}{}_1^{I}, \overset{\odot}{\alpha}{}_1^{II})$ is extremal from the definition and is feasible from the point of view of cooperation for it satisfies the equations

$$\mu_1^{I} + \mu_1^{II} = 0$$
$$\mu_2^{I} + \mu_2^{II} = 0$$

since $\mu_1^{I} = \mu_1^{II} = \mu_2^{I} = \mu_2^{II} = 0$ from the definition, and

$$\frac{\overset{\odot}{\beta}_2}{\overset{\odot}{\beta}_1} = \gamma_2$$

in view of $\overset{\odot}{\beta}{}_2^{I} = \gamma_2 \overset{\odot}{\beta}{}_1^{I}$, $\overset{\odot}{\beta}{}_2^{II} = \gamma_2 \overset{\odot}{\beta}{}_1^{II}$.

It can be concluded on the basis of the above that the pair $(\overset{\odot}{\alpha}{}_1^{I}, \overset{\odot}{\alpha}{}_1^{II})$ as one of the feasible pairs of cooperation strategies $(\alpha_1^{I}, \alpha_2^{II})$ has to satisfy also the second relation. By comparing the two relations by sides we obtain the equation:

$$\frac{D}{B^{II}} = \frac{G + \overset{\odot}{\beta}_1}{B_{21}^{II}}$$

and the formula

$$\overset{\odot}{\beta}_1 = \frac{B_{21}^{II}}{B^{II}} D - G$$

QED.

From the contents of the above theorem a conclusion can be drawn, very important from the point of view of practice, namely:

1. If characteristics A_1^I, A_2^I, b_{21}^I, b_{12}^I and A_1^{II}, A_2^{II}, b_{21}^{II}, b_{12}^{II} of both enterprises (economies) fulfill the equation

$$\frac{A_1^I + b_{21}^I A_2^I}{A_1^{II} + b_{21}^{II} A_2^{II}} = \frac{A_2^I + b_{12}^I A_1^I}{A_2^{II} + b_{12}^{II} A_1^{II}}$$

then there does not exist a cooperation strategy ensuring the possibility of increasing the overall consumption above the quantity which can be attained in case when each side is maximizing its consumption independently. Thus, cooperation does not give advantages not only when characteristics of both enterprises (economies) are identical, but also when they fulfill the equation given before.

Simultaneously, it is obviously true that

2. The greater the difference

$$\delta = \left| \frac{A_1^I + b_{21}^I A_2^I}{A_1^{II} + b_{21}^{II} A_2^{II}} - \frac{A_2^I + b_{12}^I A_1^I}{A_2^{II} + b_{12}^{II} A_1^{II}} \right|$$

the more advantageous, from the point of view of values β_1 and $\beta_2 = \gamma_2 \beta_1$, cooperation of both enterprises (economies). In this, there is $\beta_1 = \beta_1^I + \beta_1^{II}$ and $\beta_2 = \beta_2^I + \beta_2^{II}$.

The latter conclusion has also important practical significance, for it allows to choose among the numerous potential variants of cooperation the one which promises to be the most profitable for both sides. Simplicity of the formula defining δ

makes it possible to quickly order all the variants of cooperation, whose set has quite high cardinality (when the set of particular values of cooperation parameters and the set of eligible pairs of commodities being the potential objects of cooperation are both of high cardinality).

We should explain in more detail what is understood by "most advantageous" in case of cooperation as described here. Thus, we understand by this such a variant, for which one obtains the greatest increase of the overall consumption, $\beta_1=\beta_1^I+\beta_1^{II}$, $\beta_2=\gamma_2\beta_1$, of both the commodities considered, "1" and "2". Thus, the advantage from cooperation for each of the sides depends yet upon the manner in which they share the increase mentioned, and more precisely - upon the manner of dividing the summary consumption β_1 into two parts - β_1^I and β_1^{II}. The division could be unfair for one of the sides, so that, for instance, the part β_1^I accruing to the side I could be smaller than the quantity $\overset{\odot}{\beta}_1^I$, which this side would be able of ensuring for itself independently.

We shall turn to this question in the subsequent point.

Similar reservations concern the first conclusion. It is namely so that although the satisfaction of the equation mentioned there, which can also be written down in the form of

$$(A_1^I+b_{21}^I A_2^I)(A_2^{II}+b_{12}^{II}A_1^{II}) = (A_1^{II}+b_{21}^{II}A_2^{II})(A_2^I+b_{12}^I A_1^I)$$

does not lead to the increase of the quantity $\beta_1 = \beta_1^I+\beta_1^{II}$, still, in the case when $\alpha_1^I=\overset{\odot}{\alpha}_1^I$ (and $\alpha_1^{II}=\overset{\odot}{\alpha}_1^{II}$), i.e. when cooperation does take place, there also arises the necessity of dividing the quantity β_1 obtained into two parts: β_1^I and β_1^{II}. This division depends upon the prices C_1 and C_2 adopted in the exchange, and so it can bring advantage to one of the sides, of course, at the cost of the other, for the value of

$$\beta_1 = \beta_1^I + \beta_1^{II}$$

is constant.

The subsequent chapter is devoted, in particular, to the question of sharing.

BIBLIGRAPHY

1. Aganbegyan, A., Bagrinovski, K., Granberg, A.: Modele matematyczne w planowaniu gospodarczym (mathematical models in economic planning, in Polish). PWE, Warszawa 1974.

2. Ameljańczyk, A.: Niefinansowy model sterowania współpracą międzynarodową (A non-financial model of controlling the international cooperation, in Polish). *Organizacja i Kierowanie*, No. 3/1976.

3. Ameljańczyk, A., Hołubiec, J., Piasecki, S.: Optimisation of international economic cooperation. *Ricerche Economiche*, no.1, 1978.

4. Ameljańczyk, A., Hołubiec, J.: Optimal international economic cooperation and solution of a multi-person cooperative game. *Ricerche Economiche*, no.1/2, 1981.

5. Ameljańczyk, A.: Multicriterial optimisation of international economic cooperation. Vth International Conference on Systems Science, Wrocław (Poland), 1978. *Prace Naukowe ICT Politechniki Wrocławskiej*, no.39, 1978.

6. Ameljańczyk, A., Hołubiec, J.: Modelling of international cooperation in energy by multiperson cooperative game. *Proc. of the First International Conference on Applied Modelling and Simulation*, AMSE, Lyon, 1981 (vol.V).

7. Ameljańczyk, A., Hołubiec, J.: Compromise solution of multiperson cooperative game and its application to international energy consumption. *Large Scale systems, Theory and Applications*. Pergamon Press, London, 1983.

8. Ameljańczyk, A., Hołubiec, J.: The influence of political conditions on the international economic cooperation. *Proc. of SWIIS Workshop: Supplemental Ways for Improving International Stability*. Pergamon Press, Oxford, 1984.

9. Ameljańczyk, A., Hołubiec, J.: Modelling of economic cooperation among blocks of countries with different politico-economic objectives. *9th World Congress of IFAC*. Pergamon Press (IFAC Proc. Series, no.6), Oxford 1985.

10. Aumann, R.J.: Existence of competitive equilibria in markets with a continuum of traders. *Econometrica*, 34/1966.

11. Bondareva, O.N.: O teoretiko-igrovykh model'akh v ekonomik'e (On game theoretical models in economics, in Russian). *Izd. Leningradskogo Universiteta*, Leningrad 1974.

12. Czerwiński, Z.: Problematyka planowania cen w ujęciu matematycznym (The problem of price planning in the mathematical perspective, in Polish). PTPN PAN, Poznań 1963.

13. Czerwiński, Z.: Podstawowe problemy konstrukcji racjonalnego systemu cen. *Poznańskie Roczniki Ekonomiczne*. Poznań 1969.

14. Debreu, G.: Economies with a finite set of equilibria. *Econometrica*, 38, 1970.

15. Debreu, G., Scarf, H.: A limit theorem on the core of an economy. *Internat. Econ. Rev.*, 4, no.3, 1963.

16. Gale, D.: On optimal development in a multi-sector economy. *Review of Economic Studies*, 34/1, no.97, 1976.

17. Gale, D.: The Thory of Linear Economic Models. McGraw-Hill, New York 1960.

18. Gale, D.: On optimal development in a multi-sector economy. *Rev.Econ.Studies*, 34, no.1, 1967.

19. Georgesen-Roegen, N.: Some properties of a generalized Leontief model. *Activity Analysis of Production and Allocation*, T.C.Koopmans, ed., New York 1951.

20. Gambarelli, G., Hołubiec, J.: Modelling and optimization of international economic cooperation via fuzzy mathematical programming and cooperative games. *Control and Cybernetics*, no.4, 1988

21. Graham, D.: The theory of international values examined. *Qarterly Journal of Economics*, 38, no.1.

22. Hahn, F., Matthews, R.C.O.: The theory of economic growth. A survey. *Economic Journal*, 74, 1964.

23. Hołubiec, J., Piasecki, S.: La collaborazione economica internazionale e la uniformita dei prezzi internazionali (International economic cooperation and the uniformity of

international prices, in Italian). *Rivista di Politica Economica*, no. 12, 1978.

24. Holubiec, J.: Modelling of the International Economic Cooperation. *System Theory and Mathematical Economics*. Pitagora Ed., Bologna, 1986.

25. Intriligator, M.: Mathematical Optimization and Economic Theory. Prentice Hall, New York 1971.

26. Kemeny, J.G., Morgenstern, O., Thompson, G.L.: A generalization of the von Neumann model of an expanding economy. *Econometrica*, 24, no. 2, 1956.

27. Kotyński, J.: Teoria wymiany międzynarodowej a programowanie liniowe. PWE, Warszawa 1970.

28. Kulikowski, R., ed.: Modelowanie systemowe społeczno gospodarczego rozwoju kraju (Systems modelling of the socioeconomic development of a country, in Polish). PWN, Warszawa1979.

29. Leontief, W.: Factor proportion and the structure of American trade. Further theoretical and empirical analysis. *Review of Economics and Statistics*, 38, no. 4.

30. Leontief, W.: Structure of American economy 1919-1929 Cambridge-Masschusetts, Harvard Univ. Press 1941.

31. Leontief, W., Carter A.P., Petri P.A.: The Future of the World Economy. New York 1977, Oxford Univ. Press.

32. Luce R.D., Reiffa H.: Games and Decisions. Willey and Sons, New York 1957.

33. Maciejewski, W.: Algorytmy optymalizacji struktury handlu zagranicznego i kursów kierunkowych (Algorithms of optimization of the structure of foreign trade and the directional rates, in Polish). *Zastosowanie metod matematycznych do analizy ekonomicznej*. ZBKS HZ, Warszawa, 1968.

34. Maciejewski, W.: Ekonometryczne modele wymiany międzynarodowej (Econometric models of international trade, in Polish). PWN, Warszawa 1981.

35. Mycielski, J., Trzeciakowski, W.: Critères du choix des investissements rapidement rentables (Criteria of choice of quick

repayment investments, in French). *Economies and Societies*, no.1, 1970.

36. Mycielski, J., Rey, K., Trzeciakowski, W.: Decomposition and Optimization of Short-Run Planning in a Planned Economy (T.Barna, ed.). London 1963.

37. Nash, J.F.: Equlibrium points in *n*-person games. *Proc.Nat.Acad. Sciences*, USA, 36, 1950.

38. von Neumann, J., Morgenstern, O.: Theory of Games and Economic Behaviour. Princeton 1974.

39. Nikaido, H.: Convex Structures and Economic Theory. Academic Press, New York - London 1968.

40. Pawłowski, Z.: Ekonometria (Econometrics, in Polish) PWN, Warszawa 1978 (fifth edition).

41. Piasecki, St., Ameljańczyk, A.: A control of international economic cooperation. IVth International Conference on Systems Science, Wrocław, Poland, 1977. *Prace Naukowe ICT Politechniki Wrocławskiej*, no.47, 1977.

42. Piasecki, St., Hołubiec, J.: Sterowanie wymianą gospodarczą (Controlling the economic exchange, in Polish) *Prace IBS PAN*, no.32, Warszawa 1979.

43. Piasecki, St., Hołubiec, J.: Wieloletnia koordynacja międzynarodowego rozwoju gospodarczego (Multiannual coordination of the international economic development, in Polish). *Prace IBS PAN*, no.52, Warszawa 1980.

44. Piasecki, St., Hołubiec J.: International economic cooperation and the uniform international prices (in polish). Prace IBS PAN Nr 52, Warszawa 1980.

45. Piasecki, St., Hołubiec, J.: Pewne zagadnienie międzynarodowej współpracy gospodarczej (On a certain problem in international economic cooperation, in Polish). *Prace IBS PAN*, no.77, 1981.

46. Piasecki, St., Hołubiec, J., Ameljańczyk, A.: Międzynarodowa kooperacja gospodarcza (The International Economic Cooperation, in Polish). PWN, Łódź - Warszawa 1982.

47. Piasecki S.: Model of Socio-Economic National Development

(in polish). Prace IBS PAN, No 164 Warszawa 1988.

48. Piaszczyński, W.: Matematyczne modele teorii handlu międzynarodowego (Mathematical Models of the Theory of International Trade, in Polish). PWE, Warszawa 1974.

49. Rosati, D.: Polityka eksportowa. PWE, Warszawa 1990.

50. Rosenmüller, J.: Kooperative Spiele und Market (Cooperative Games and Market, in German). Springer Verlag, Berlin - Heidelberg - New York 1971.

51 .Roth, A.E.: Subsolutions and supercore of cooperative games. *Mathematics of Operations Research*, vol.1, no.1, 1976.

52. Shapley, L.S., Shubik, M.: On market games. *J.Economic Theory 1*, no.1, 1969.

53. Shubik, M.: Edgeworth market games. *Annals of Math. Studies*, vol.IV, no.40, 1959.

54 .Solow, R.M.: A contribution to the theory of economic growth. *Quarterly Journal of Economics*, 70, 1956.

55. Shagalov, G.L.: Problemy optimalnogo planirovaniya vneshne-ekonomicheskikh sviazey (Problems of optimum planning of external economic relations, in Russian). Izd. Moskva 1973

56. Trzeciakowski, W.: Modele pośredniego kierowania gospodarką planową w sterowaniu handlem zagranicznym (Models of indirect management of a planned economy in the control of foreign trade, in Polish). PWE, Warszawa 1975.

57. Tsukui, J.: Turnpike theorem in a generalized dynamic input-output system. *Econometrica*, 34, no.2, 1966.

58. Uzawa, H.: Optimal growth in a two-sector model of capital accumulation. *Review of Economic Studies*, 31, 1964.

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ISBN 83-90-00412-5-1