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PREDICTION IN ECONOMIC GEOGRAPHY

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The bases for forming a new paradigm in geography are four principle methodological tendencies which can be expressed in the movement:

1) from examining simple relations to examining more complex structures and "wholes" rather than "parts,"
2) from a qualitative to a quantitative approach,
3) from particularizing to generalizing and,
4) from a genetic to an explanatory and predictive approach.

The last tendency, particularly when it is closely connected with the others, is of great importance for assuring the right place for geography among other disciplines. Scientific interest in prediction, in particular the ability to form statements concerning the future, is becoming a basic criterion for assessing the value of certain disciplines.

The reason for this is, that regardless of philosophical viewpoint and methodological opinion, it has been generally agreed that the essential statements of value are those which provide the possibility for making an accurate forecast.

Scientific prognosis is the methodology of interpreting data from the predictive viewpoint and is not a theory of the future. In all scientific disciplines and especially in the social sciences a newly organized scientific movement has been developing taking up the problems of prediction, see Madej [*35*] and de Jouvenel [*29*]. In connection with this the question of the basis for prediction in geography arises. This was noted by Hartshorne [*25*], Chorley and Haggett [*12*] and Sauszkin [*53*].

Some very interesting research has been reported on prediction concepts and instruments in social and economic science as given by Bell [*3*], Bird [*4*], Massenet [*37*, *38*], Pawlowski [*49*], Siciński [*54*], and Wold [*61*]. I would like to suggest some slight generalizations of the concepts which appear in the social sciences and economic geography; I would also like to make a suggestion to facilitate the actual use of those concepts.

I shall now examine briefly the concepts and logical nature of scientific prediction in economic geography.

Scientific predictions are based on reasons which the author must present precisely. Prediction, however, is a definite process of conclusion, which helps to achieve concrete results in the form of a forecast hypothesis or a prognosis. The forecast hypothesis which results from this kind of deduction is formulated for further analysis and verification. A prognosis is a proposition about the future which has not been formulated for actual verification.

Contemporary methodology of science assumes that the basis for prediction is, above all, found in the laws of science.

According to Bunge [*6*, p. 307] scientific prediction may be defined as the deduction of propositions concerning as yet unknown or unexperienced facts on the basis of general laws, and of items of specific information. The logical structure of scientific prediction is the same as that of scientific explanation; both are consequences of the conjunction of laws and particular pieces of information. But the identity in logical structure does not entail an identity in nature or kind; prediction is not epistemologically the same as description and explanation, because prediction is usually affected by a peculiar uncertainty of its own. The uncertainty of prediction stems partly from the incompleteness of description and explanation, but in prediction an additional uncertainty appears, namely, the one associated with the unexpected emergence of new information or new conditions.

If we assume the principle that the bases for prediction are scientific laws conceived of only as strictly universal statements and theories, then the possibilities for prediction in human geography and the other social sciences which show a low level of achievement in formulating laws and theories would be confined. These disciplines have not managed to achieve a logically coherent system of general statements, i.e., laws and hypotheses in the form of theories [*11*].

This happens because of the high degree of complication, the large number of conditions, and the complexity of causal connections in social-economic phenomena. This makes it very difficult to ascertain regularities and to build up hypotheses. But the low frequency of observed regularities is one of the difficulties besetting the disclosure of laws in any field of investigation.

In economic geography regularities are seldom observed. They are usually inferred or reconstructed, that is, first assumed and then tested. In order to find regularities we must make extensive use of abstraction, which alone can go beyond the appearance into the essence of things. In other words, the establishment of laws and theory in social science requires the formulation of cognitive models.

Omitting at this point any discussion on the subject of model conception in science, we can nevertheless state that a theoretical model is a collection of assumptions which makes the solution of the problem under examination possible, [*9*, *10*]. These assumptions are usually a description or representation of a certain group of events or things. They are often formed for comparatively simple patterns of events in the hope that the resulting conclusions can be transferred to more complicated patterns [*22*].

The essential element in this kind of procedure is that the model involves assumptions for simplifying the problem. This simplification can depend, among other things, on making even fictious assumptions in order to strengthen our means of inference, e.g., assuming that certain information concerning the probability distribution of certain events or processes is known or that certain constraints are operative. As long as all variables have not been replaced by constants, the model permits us to infer structure. From the structure we obtain empirical dependence by replacing each variable by a constant value defined by the functions connecting the values concerned. The cognitive model is then constructed; we may hope to know from it the behaviour of a certain system, and possibly foresee its behaviour in the future.

Isard [*28*, p. 593] maintained that perfect projection and understanding of society would necessitate a complete general interdependence theory, fully tested and set down explicitly in quantitative, operational form. But no such theory currently exists or is ever likely to be attained.

Prediction concerning social phenomena in geographic research is characterized by three features.

First, prediction concerns mass phenomena, and it is easy to see why this is so. Most hypotheses and regularities are statistical, established empirically or on the basis of theoretical models, and they are not supposed to permit the formulation of precise predictions about singular events. They help in foreseeing collective properties, that is properties of large populations, that are similar in some respect.

Second, the knowledge gained in making predictions can very seriously affect the evolution of phenomena which are the subject of prediction. Announcing the forecast can induce a modification of action that can lead to the self-destruction or self-realization of the forecast.

Third, social phenomena develop not only according to their own laws, but depend also on the material base, that is, they depend on technical progress and geographical environment.

In the field of economic geography, prediction is an indication of changes likely to occur in the spatial patterns of social organization and cultural forms based on the close connection between the evolution of cultural forms over time, their structure, and diffusion over space.

The present state of prediction methodology is characterized by a great variety of prediction methods which vary both with respect to their logical forms and their problem-solving objectives.

Using E. Jantsch's terminology we can distinguish between *explorative* forecasting which begins with the assured basis of present knowledge and is oriented towards the future, and *normative* forecasting which first assesses future goals, needs, and desires, and then works backward to the present [*4*, p. 71].

The methodology of normative forecasting is based on decision theories such as the theory of marginal utility, programming, and game theory. Due to their normative character, these theories concern not prediction but rational choice. By rational behaviour, e.g., in the sense of maximizing or minimizing behaviour, we understand a choice of decisions from the collection of alternatives which will achieve a definite aim. This whole question which has been the subject of numerous studies requires, however, a separate analysis in the context of economic geography, see Churchman [*13*] and Giedymin [*22*].

The basic division is between *quantitative* and *non-quantitative* approaches. Although both types involve risk, with the development of modern statistical methods we can better estimate within probability ranges the errors to represent risk. The use of statistics and mathematics, however, has not eliminated subjectivity with respect to judgment, the method of prediction, the theory upon which to operate, the variables to select, the methods to use, or the qualitative interpretation and inferences to be drawn from empirical results. Experience, judgment, knowledge, and inclination have to be employed to temper the forecast and perceive the hidden factors which often nullify the accuracy of estimates [*23*].

There are many principles of inference in forecasting and many techniques of describing a prognosis based on them. Depending upon the character of the problem, the specific features of the phenomena which we want to foresee, the period of time, and also whether the inference is a single or repeated one, different methods, sometimes complementary to each other, may be used.

Quantitative prediction methods which are applied or can be applied to examine the changes in spatial patterns, are in fact reduced to two types of extrapolation: 1) extrapolation of endogenous variables in the descriptive models, and 2) extrapolation of the stochastic processes.

The division, however, is not logically separate, but it is based on differentiation of two basic conceptions of understanding reality in economic geography: structure and process. This is not equal of course to the division between static and dynamic approaches.

The extrapolation of endogenous variables in descriptive models has been particularly applied and justified on the grounds of the classical econometric theory of estimation. Its backgrounds have been worked out by economists associated with the Cowles Commission for Research in Economics. This is a very popular theory which does not need to be introduced here. We only need to mention that its stochastic or random character is strongly emphasized. According to this theory, the endogenous variables of the econometric models are random variables with the induced distribution determined above all by the distribution of the random components.

From the practical point of view, the most important way of making use of the descriptive models is the extrapolation of some values which appear as endogenous variables in the model. The idea of extrapolation itself ought to be understood quite broadly as inference beyond a statistical sample.

It is difficult to introduce only the outline of the method of extrapolation based on the theory of econometric models. I must emphasize that there can be no uniquely best principle of extrapolation useful for all types of models. The principle of prediction such as unbiased prediction, prediction according to the maximum probability, and the principle of least-risk prediction depends on the circumstances and especially on whether there will be only one prediction or whether the process of prediction will be repeated often. So, leaving aside the details concerning the technique of prediction, the basic foundation of the classical theory which when realized makes good extrapolation possible ought to be considered.

The difficulties which are connected with the realization of these assumptions help explain the still very low prognostic effectiveness of descriptive models in economic geography. These models chiefly refer to spatial structure and spatial interdependence in the human pattern, and they can be thought of as describing characteristics of spatial pattern behaviour.

If we examine the problem of the assumptions of prediction theory we can distinguish as Pawlowski does [*49*, p. 17] three conditions for good extrapolation: 1) knowledge of the model for prognostic variation, 2) stability of structural relation and a random component in time, and 3) knowledge of the explanatory variate value during the forecast period.

The *first* condition concerning the structure of the model means that not only the analytical form of the relation and the numerical value of structural parameters of the model must be known, but also the parameters of the stochastic structure of the model. Research practice deals with two problems: a) the choice of the descriptive equation, b) the statistical information on which the parameters will be estimated.

The question of the choice or form of the best fitting function is one of the most difficult problems. We can ex post facto determine whether an essential difference between the goodness of fit of two different curves exists, but this is not always possible, e.g., between a linear and an exponential trend. In the models applied in economic geography the lack of well-developed theories which can be used to set up hypotheses about the form of the function makes things more difficult.

The typical example is in interaction hypotheses based on the gravity model where the different types of function describe the same problem situation, and the lack of theory prevents us from identifying a priori a problem situation to which the appropriate type of function can be applied [*8*].

I shall not deal here with the problematics of gathering information and bringing "rough" data to such a form that they could be used for model estimation. However, great care should be taken to assess the representative character of these data so that the whole procedure is based on the assumption that exogenous variables of the model are random variables. In connection with this, care should be taken of the fact that mathematical statistics entitles us to use the notion of random sampling only in such situations; the possibility of multiple sampling conditions may exist, see Czerwiński [*17*]. So, only the scheme "population-random sample" permits us to use the concept of the value of the variance of estimators.

In geographical research we operate with a full set of data, and also very often with such values as distance of migration and similar measures which cannot be regarded as random samples. One of the elementary conditions in random sampling is that each population element must have an identical chance of entering the sample. Examining such values as distances between all towns in a given region as a sample is rather fictitious. Hence in research in economic geography we deal not so much with estimation, but with an adjusting function.

The *second* condition says that the structure of the phenomena, the relationships described by the model, and the distribution of the random component remain steady. This stability is required from the moment a sample is taken until the time of prognosis. The development of mathematical statistics has enabled us to examine this stability and to estimate the directions and eventual changes in time [*48*].

The increase of variance in the random component signals that secondary factors grow more and more important, while the role of the main factors diminishes. In such cases, the principle of prediction ought to be based on the analysis of these additional factors.

If we omit the rapid changes which radically change the structure, which Lange [*34*, p. 25] called disastrous, such as a social revolution, technical revolution, wars, or elemental disasters, so in research in economic geography two groups of causes of regularity of such changes ought to be distinguished: demographic movement and technological development. That means, in conclusion, that the principle of inference in the distant future is limited to conditions of structural dependence which do not change very often.

The *third* condition is that the value of exogenous variates during the prediction period is known. There are some methods of profiting also from nonstatistical information concerning the future state of exogenous quantity.

This question does not appear in the case of the models of time trends in which time appears as an exogenous variate. This kind of prediction, however, is least justified, because when a trend is assigned, we do not know why a certain quantity grows according to this or that curve. Increasing the length of the trend does not increase the certainty of the prognosis, because we then need to consider the influence of future circumstances which do not yet exist. Extrapolation of the trend can also be one of the methods used for defining the value of the exogenous variable during the period of prediction.

Realization of the above mentioned conditions both in econometric work and specially in research in economic geography gives rise to certain difficulties and doubts about the principles of extrapolation. Estimated models vary greatly in accuracy when adjusted to the results of observation. The question arises then, can we estimate errors which occur when we base the quantity prognosis by a definite model worked out numerically?

In fact, we cannot evaluate the error in advance; this can be done only when we compare a prognosis with the real quantity. But we can estimate the probability of making an error of definite value. For this kind of estimation certain assumptions regarding the random character of some variables and assumptions about the form of their distribution are required. These can be realized only by repeated use of the model, but this is rather rare in social science. Of course with control the errors can be reduced or minimized—a condition generally absent in social phenomena. This is why a model does not represent a prediction of a single event but of some expected value. The estimate tells us only that we do not fail more than 20 percent of the time.

Without a closer examination of some further and more detailed questions and techniques connected with the principles and methods of extrapolation based on the classical theory of econometric models, we must, however, express doubts about their universal application in social research and especially in economic geography. This theory as it seems overestimates the role of initial probability which is low and without a rationale in many geographical models. It is clear, therefore, that in terms of these conditions many standard forecasts are theoretically and statistically incomplete.

There are many examples in the literature of economic geography of hypotheses based on regression models as gravity models which have similar grounds for the failure of specific prediction, see Olsson [43] and Chojnicki [8, 10]. These weaknesses result above all from difficulties which appear in connection with the realization of the assumptions of the classical theory of prognosis, and especially from the realization of assumptions about randomness. The use of certain notions of mathematical statistics beyond the range in which they may be applied leads to results which have no clear-cut interpretation, see Czerwiński [18].

A critical opinion in this matter does not mean we ought to give up such an approach. But it does require a discussion on the rationale of these kinds of methods, since this is one of the basic ways of predicting.

We can also approach the problems of prediction in economic geography from a slightly different point of view, namely *extrapolation of the stochastic processes*. The theory of stochastic processes refers to the laws of distribution of random variables which in some way depend on realizations of other random variables antecedent in time.

The mathematical treatment of stochastic process models is beyond the scope of this paper, but I wish to present only some remarks concerning the forecasting problem. The research in the field of economic geography and related disciplines shows that the applications of models of stochastic processes mainly include Markov chains and simulation models.

A Markov chain is a mathematical model for describing a certain type of process that moves in a sequence of steps through a set of states [31, 32]. A Markov chain forms a subset of the Markov process with the added condition of stationarity. The initial probability vector and the transition matrix completely determine the Markov chain process. The few applications of Markov chains in spatial research were, above all, of analytical and exemplary character. But according to Harvey [27, p. 582] the Markov chain technique has considerable potential as an aid to research into problems of evolution in economic geography, since it enables us to treat temporal dependence of events within a system of geographic locations, and to examine equilibrium as a statistical state in terms of the actual processes at work in society.

A basic role in this model is played by the transition matrix. In the practical application of Markov chain models the transition probabilities are usually not known and they ought to be statistically estimated. The estimators of these probabilities can be relative frequencies of realization of suitable random events, i.e., relative frequency of passing the structure from one state to another state in one step. The proper estimation of the transition probability makes a foundation for good prediction, but their use for long-term forecasting is limited. If they are stable over time then further forecasts about the development of the system may be computed.

Olsson and Gale [47] provide some propositions for relaxing several limitations connected with the application of traditional Markov models in spatial research. They suggest that the ordinary matrices be extended to several dimensions and argue that the condition of a linear sequential operator be modified in order to account for neighborhood and contiguity effects.

Further possibilities for expanding the application of stochastic process models are connected with the application of the theory of stationary stochastic processes to prediction (see Gichman and Skorochod [21], Rosenblatt [52] and Wiener [60]). Some economic series from which the trend and the cyclic fluctuation have been removed can be treated temporarily in some cases as the realization of a stationary process. The theory of these processes supplies a key very similar to Markov chains, which helps to make effective prediction possible, which means to foresee the further realization of the process with the smallest failure possible.

Recently, *simulation* models have evoked hopes in economic geography of providing methods to examine more complex problems, by means of which the impossibility of carrying on experiments could be replaced.

Simulation is, in effect, experimentation on a model rather than on the phenomenon itself; that is, it is vicarious experimentation [2, p. 348]. The essence of simulation is to imitate the run of some process and follow its evolution. The basic category of numerical simulation is the Monte Carlo technique. According to Ackoff [2, p. 352] the use of the Monte Carlo technique involves three research decisions: 1) how to obtain a set of random numbers; 2) how to convert these numbers into random variates from some specified probability distribution, and 3) how to increase the efficiency of estimates obtained from the sampling process.

The results of the application and discussion of numerical simulation in economic geography, as given by Garrison [20]; Haggett [24]; Harvey [27]; Malm, Olsson, and Wärneryd [36]; Morrill [39, 40, 41]; Olsson and Gale [47]; Pitts [50]; Wärneryd [58]; and Yuill [62], show that:

1) Simulation is well suited to an experimental process in time in which a complex of probabilities interact to produce typical patterns, and for a process the patterns of which are a product of individual decisions [20, p. 100].
2) Sampling on probability distributions can produce a very wide range of results, and the procedure is only meaningful if we take quite a large sample of events which are independent of one another [27, p. 385].
3) The simulated results are less precise than the purely analytical ones, partly because of the built-in random factor and partly because a unique result is produced every time simulations of a non-deterministic model are carried out [59, p. 42].
4) The greatest problem with geographical simulation is to find quantitative methods by which the simulated results can be compared with reality [59, p. 43].

It is important to note that the applications of simulation models in geography are not of strict predictive character but are mainly of analytical value.

The predictive value of simulation depends on the realization of some assumptions:

1) derivation of more realistic rules for the game which have historical and spatial validity;
2) derivation of a set of initial probabilities which have empirical validity and a theoretical interpretation;
3) assigning probabilities to various alternatives and comparing the different results;
4) establishing the rules of correspondence between some assumptions of the model and reality concerning

spatial characteristics, as for example the spatial probability field.

The effective application of extrapolation methods to forecasting requires the realization of two assumptions: first, that in relation to the output situation no rapid change will take place; and second, that analysis of stability of all compound elements of the fragment of reality examined is possible.

The extrapolation method requires, above all, a critical effort in order to distinguish problems for which extrapolation is possible. So, it is necessary to detach such elements which in smaller or larger degree do not permit the application of extrapolation methods. Such analysis is possible in some degree in connection with the variation of existing elements and the relationships among them. However, methods for foreseeing the emergence of new elements and new kinds of relationships do not exist. Technical, social, and organizational revolutions are good examples. This forms one of the basic barriers that limits the application of prediction methods based on extrapolation which is the method of short-term prognosis.

The extrapolation method can be expanded and enriched by topological analysis in geography. If we assume that prediction is based on examining changes which appear in the spatial structure as a result of evolution, then these changes can be regarded as a deformation in the geometry of all types of economic and geographic spaces. If we knew the law of this deformation we could easily show the picture of the future. The development of application of network models based on topological geometry gives some possibilities of examining the invariabilities of this kind of deformation. A good example of this is the work of Kansky [*30*] which elaborated a workable predictive model of a transportation network based on evolutionary and spatially stable, functional relationships between a network structure and regional characteristics.

Finally, I must emphasize that the degree of accuracy of forecasting in social science depends on a host of factors such as the value of models, information, and inference, and it is almost impossible to establish all those conditions that will make one prediction more accurate than another. However, as pointed out by Bunge [*6*, p. 330], very few facts in the concrete world are predictable with certainty, and none can be predicted in all details because scientific information regards singular facts, none of which are ever complete and exact.

LITERATURE CITED

1. Ackerman, E. A. *Geography as a Fundamental Research Discipline*. Chicago: Department of Geography, University of Chicago, Research Paper 53, 1958.
2. Ackoff, R. L. *Scientific Methods*. New York: John Wiley and Sons, 1962.
3. Bell, D. "Douze modes de prevision en science sociale. Enumeration preliminaire." *Bulletin Sedeis* 863, *Supplément Futuribles* 64 (1963).
4. Bird, J. "Forecasting and Geography," *The Geographical Journal*, 135 (1969), pp. 69–72.
5. Braithwaite, R. B. *Scientific Explanation*. New York: Harper, 1960.
6. Bunge, W. M. *Causality: the Place of the Causal Principle in Modern Science*. Cambridge, Mass: Harvard University Press, 1959.
7. de Cani, J. S. "On the Construction of Stochastic Models of Population Growth and Migration," *Journal of Regional Science*, 3 (1961), pp. 1–13.
8. Chojnicki, Z. *Zastosowanie modeli grawitacji i potencjalu w badaniach przestrzenno-ekonomicznych* (The Application of Gravity and Potential Models in Spatial Economic Research), Komitet Przestrzennego Zagospodarowania Kraju, Polska Akademia Nauk, Studia, XIV, Warszawa, 1966.
9. Chojnicki, Z. "Modele matematyczne w geografii ekonomicznej," *Przeglad Geograficzny*, 39 (1967), pp. 115–134.
10. Chojnicki, Z. "Some Theoretical Aspects of Applications of Mathematical Models in Economic Geography," *Geographia Polonica*, 15 (1969).
11. Chojnicki, Z. and A. Wróbel. "Rola i charakter badań teoretycznych w geografii ekonomicznej," *Przeglad Geograficzny*, 39 (1967), pp. 103–113.
12. Chorley, R. J. and P. Haggett. *Models in Geography*. London: Methuen, 1967.
13. Churchman, C. W. *Prediction and Optimal Decision*. Englewood Cliffs: Prentice-Hall, 1961.
14. Claeson, C. F. "Distance and Human Interaction: Review and Discussion of a Series of Essays on Geographic Model Building," *Geografiska Annaler*, 50B (1968), pp. 143–161.
15. Cole, J. P. and C. A. M. King. *Quantitative Geography*. London: John Wiley and Sons, 1968.
16. Curry, L. "The Random Spatial Economy: an Exploration in Settlement Theory," *Annals of the Association of American Geographers*, 54 (1964), pp. 138–146.
17. Czerwiński, Z. "O interpretacji równan ekonometrycznych," (On the Interpretation of Econometric Relations.) *Przeglad Statystyczny*, 13 (1966), pp. 229–243.
18. Czerwiński, Z. *Wstep do ekonometrii*, Wyzsza Szkola Ekonomiczna, Poznań, 1967.
19. Fleisher, A. "On Prediction and Urban Traffic," *Papers, Regional Science Association*, 7 (1961), pp. 43–50.
20. Garrison, W. L. "Toward Simulation Models of Urban Growth and Development," *Proceedings of the IGU Symposium in Urban Geography, Lund, 1960*. Edited by K. Norborg. Lund Studies in Geography, Human Geography, Ser. B, 24 (1962), pp. 91–107.
21. Gichman, I. I. and A. W. Skorochod. *Wstep do teorii procesów stochastycznych*, Warszawa, PWN, 1968.
22. Giedymin, J. *Problemy, zalozenia, rozstrzygniecia*. (Sum. Questions, Assumptions, Decidability.) Poznań: Polskie Towarzystwo Ekonomiczne, 1964.
23. Greenwald, W. J. *Statistics for Economics*. Columbus, Ohio: Charles E. Merrill Books, 1963.
24. Haggett, P. *Locational Analysis in Human Geography*. London: Edward Arnold Publishers, 1965.
25. Hartshorne, R. *Perspective on the Nature of Geography*. Chicago: Rand McNally, 1959.
26. Harvey, D. W. "Geographical Processes and the Analysis of Point Patterns: Testing a Diffusion Model by Quadrat Sampling," *Transactions and Papers*, Institute of British Geographers, 40 (1966), pp. 81–95.
27. Harvey, D. W. "Models of the Evolution of Spatial Patterns in Human Geography," *Models in Geography*. Edited by R. J. Chorley and P. Haggett. London: Methuen, 1967.
28. Isard, W. *Methods of Regional Analysis: an Introduction to Regional Science*. New York: John Wiley and Sons, 1960.
29. de Jouvenel, B. "De la conjecture." *Bulletin Sedeis, Futuribles* 27 (1962).
30. Kansky, K. J. *Structure of Transportation Networks: Relationships between Network Geometry and Regional Characteristics*. Chicago: Department of Geography, University of Chicago. Research Paper 84, 1963.
31. Kemeny, J. G. and J. L. Snell. *Finite Markov Chains*. Princeton: D. Van Nostrand Company, 1960.
32. Kemeny, J. G. and J. L. Snell. *Mathematical Models in the Social Sciences*. Boston: Ginn and Company, 1962.
33. Krumbein, W. C. and T. A. Graybill. *An Introduction to Statistical Models in Geology*. New York: McGraw-Hill Book Company, 1965.
34. Lange, O. *Wstep do ekonometrii*. Warszawa, PWN, 1961.
35. Madej, Z. "Metody przewidywania i ksztaltowania przyszlości," *Gospodarka Planowa*, 5 (1967), pp. 4–10.
36. Malm, R., G. Olsson, and O. Wärneryd. "Approaches to Simulations of Urban Growth," *Meddelanden Fran Göteborgs Universitets Geografiska Institution*, 81 (1966), pp. 9–22.
37. Massenet, M. "Etudes methodologiques sur le futuribles," *Bulletin Sedeis, Futuribles*, 52 (1963).
38. Massenet, M. "Les methodes de prevision en sciences sociale," *Bulletin Sedeis, Futuribles*, 66 (1963).
39. Morrill, R. L. "Simulation of Central Place Patterns over Time," *Proceedings of the IGU Symposium in Urban Geography, Lund, 1960*, Edited by K. Norborg. Lund Studies in Geography, Human Geography, Ser. B., 24 (1962), pp. 109–119.
40. Morrill, R. L. "The Development of Spatial Distributions of Towns in Sweden: an Historical-Predictive Approach," *Regional Development and Planning*. Edited by J. Friedman and W. Alonso. Cambridge, 1964, pp. 173–86.
41. Morrill, R. L. "Expansion of the Urban Fringe: a Simulation Experiment," *Papers, Regional Science Association*, XV (1965), pp. 185–199.
42. Olsson, G. *Distance and Human Interaction: a Review and Bibliography*. Philadelphia: Regional Science Research Institute, 1965.

43. Olsson, G. "Distance and Human Interaction: a Migration Study," *Geografiska Annaler,* 47B (1965), pp. 3–43.

44. Olsson G. "Central Place Systems, Spatial Interaction and Stochastic Processes," *Papers, Regional Science Association,* 18 (1967), pp. 14–45.

45. Olsson, G. "Localiseringsteori och stocastiska processer," *Regionale Analysemetoder,* Norsk Institutt for by-og Regionforskining, Oslo, 1967, pp. 55–86.

46. Olsson, G. "Complementary Models: a Study of Colonization Maps," *Geografiska Annaler,* 50B (1968), pp. 115–32.

47. Olsson, G. and S. Gale. "Spatial Theory and Human Behavior," *Papers, Regional Science Association,* 21 (1968), pp. 229–42.

48. Pawlowski, Z. *Wstep do statystyki matematycznej.* Warszawa, PWN, 1966.

49. Pawlowski, Z. *Teoria prognozy ekonometrycznej w gospodarce socjalistycznej.* Warszawa, PWN, 1968.

50. Pitts, F. R. "Problems in Computer Simulation of Diffusion," *Papers, Regional Science Association,* 11 (1963), pp. 112–19.

51. Rogers, A. "A Markovian Policy Model of Interregional Migration." *Papers, Regional Science Association,* 17 (1966), pp. 205–224.

52. Rosenblatt, M. *Procesy stochastyczne.* Warszawa, PWN, 1967.

53. Sauszkin, J. G. "Prognoz w ekonomiczeskoj geografii." *Westnik Moskowskogo Uniwersiteta,* Geografija, 5 (1967), pp. 39–45.

54. Sicinski, A. *Prognozy a nauka.* Warszawa: Ksiazka i Wiedza, 1969.

55. Simon, H. A. "Causal Ordering and Identifiability," *Essays on the Structure of Social Science Models.* Edited by A. Ando, F. M. Fisher, and H. A. Simon. Cambridge, 1963, pp. 5–31.

56. Smith, P. E. "Markov Chains, Exchange Matrices and Regional Development," *Journal of Regional Science,* 3 (1961), pp. 27–36.

57. Ulam, S. M. *Problems in Modern Mathematics.* New York, 1960.

58. Wärneryd, O. "Simulering och regional analys," *Regionale Analysemetoder,* Norsk Institutt for by-og Regionforskining, Oslo, 1967, pp. 5–54.

59. Wärneryd, O. *Interdependence in Urban Systems.* Göteborg: Regionkonsult, 1968.

60. Wiener, N. *Extrapolation, Interpolation and Smoothing of Stationary Time Series.* Cambridge, 1964.

61. Wold, H. "Forecasting by the Chain Principle," *Econometric Model Building.* Edited by H. Wold. Amsterdam: North-Holland Publishing Company, 1964, pp. 5–36.

62. Yuill, R. S. *A Simulation Study of Barrier Effects in Spatial Diffusion Problems.* Ann Arbor: Michigan Inter-University Community of Mathematical Geographers, Discussion Paper 5, 1965.