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Nobel Laureate
Trygve Haavelmo

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When the Norwegian professor Trygve Haavelmo was announced as the 1989 Nobel prize winner in economics, he was completely unknown to the general public in his own country. Although intensely interested in policy questions, he has never entered public debate and has always avoided publicity. But Haavelmo had an enormous influence on the community of Norwegian economists as the dominant teacher of two generations. In addition, as Schumpeter noted in the *History of Economic Analysis*, Haavelmo, "during his brief sojourn in the United States, without holding a teaching position, exerted an influence that would do credit to the lifetime work of a professor" (1954, p. 1163). Yet today, few younger economists outside of Norway have read anything he wrote, and even fewer are acquainted with his contributions outside the field of econometrics.

Haavelmo was in the United States from 1939 to 1947, and in this period he published most of his path-breaking contributions to econometrics for which the Nobel committee awarded him the prize. Yet, it is a false impression that he has been a less active researcher since then. On the contrary, he has been, and still is, intensively occupied with research and his list of publications after 1947 contains more than 100 items. In the present article we give a brief review of some of his work. His contribution to econometrics in the 1930s and '40s has been celebrated and described by numerous authors recently. Therefore, we shall only give a brief review of those contributions here. Moreover, among the many articles, books, lecture notes and research memoranda that Haavelmo wrote after he was appointed as a professor in econometrics in 1948, only two articles and some notes for students were on econometrics (in the narrow sense).

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Instead, we shall focus more on the remaining 90 percent of Haavelmo's works. His research on economic theory was mainly reported in six books, of which the first two appeared in English, the latter four in Norwegian. Some research was also reported in scientific articles, most often published in *festschrifts* for his friends. Then there are a number of articles on policy questions in Norwegian journals, and finally close to 40 volumes of mimeographed lecture notes.

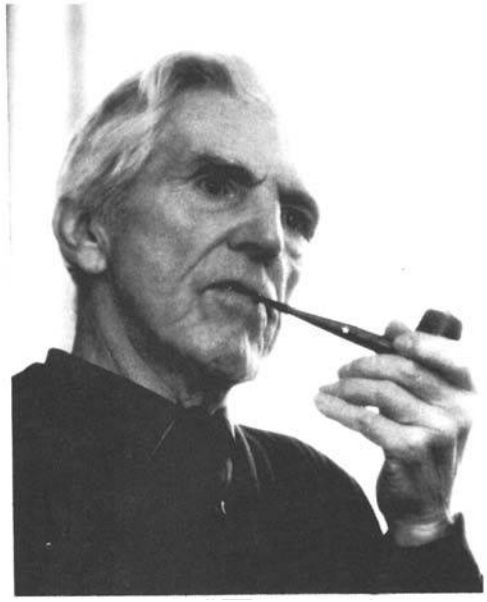
In the wide range of subjects covered in Haavelmo's writings, some themes seem to have occupied him more than others: the relationship between population, natural resources and growth; investment and capital theory; the notion of equilibrium and disequilibrium; the nature and stability of preferences; the nature and problems of democracy. Before we turn to these issues, however, let us briefly go through Haavelmo's academic background.

Background

Economists from Oslo played a key role in the transformation of economics from an armchair activity to an empirical science expressed in mathematical language between 1930 and 1960. When Haavelmo, born outside Oslo in 1911, began his studies, economics had been taught at the University of Oslo for 100 years. The professors had been learned and distinguished people, highly respected in society, but their scientific contributions were for immediate domestic consumption only. In 1931, when Haavelmo was a first-year undergraduate, however, the University called one of its former students, Ragnar Frisch (1895–1973) to a new professorship. The same year Frisch had taken part in the founding of the Econometric Society. He had been visiting universities in Europe and the United States for several years, and came home with an ambitious program for making economics an empirical science by employing the tools of mathematics and statistics.

Frisch, with his sweeping energy, soon became the dominating person in the small economics department in Oslo. As Haavelmo later put it: "... as seen by the students, the economics curriculum shook in its foundations." Haavelmo began as Frisch's assistant in 1933. During 1938–39 Haavelmo held the position as a Lecturer at the University of Aarhus, Denmark, before he went to the United States as a Fulbright scholar in 1939. There he did research at the Cowles Commission and at various American universities during the years 1939–47. His doctoral thesis—"The Probability Approach in Econometrics"—was completed at Harvard in 1941 and submitted to the University of Oslo after the end of war. He was appointed full professor at the University of Oslo in 1948, a position he held until he became emeritus in 1979.

To this chronicle should be added some facts about the other sides of Haavelmo's life; for instance, his favorite mode of transport, Harley-Davidson motorcycle, and his love for fishing and skiing. Few things, however, would



Trygve Haavelmo

annoy Haavelmo more than wasting the pages of scientific journals with such matters. Let us therefore stop by just adding a few words about his professional activities outside of academia. In between his scientific contributions, he served his country both in the shipping administration in New York and as a trade secretary in Washington from 1942–45. When he returned to Oslo in 1947, it was to head a government office preparing the national economic plans. In that capacity he was for a year one of the leading figures in the reconstruction of the Norwegian economy. In 1965 Haavelmo involved himself in party politics, when he became member of the Labour party committee for economic policy.

The Probability Approach in Econometrics

Haavelmo has been best known for his work on identification, estimation and testing in models where the variables are determined by a system of simultaneous equations. It was his contributions in this area and in introducing probability theory to econometrics in his dissertation and in his articles in *Econometrica* through the 1940s which the Swedish Academy of Sciences cited as the main reason for awarding him the prize.

When one looks at Haavelmo's dissertation, one is struck by its broad scope. The book could be classified as philosophy of science as well as econometrics. The title of the first chapter—"Abstract models and reality"—is indicative. The purpose of the book is really to convince economists that they should

accept probability models as a basis for their research. Less than half the book is devoted to the particular issues raised by the simultaneity problem.

Today every economist has completed a course in econometrics and has been taught to use probability models as a matter of course, so it is easy to overlook what a revolution it was when this tool was first taken into use. As with most revolutions it did not go without resistance, or, as Haavelmo put it in his preface, "...the adoption of definite probability models has been deemed a crime in economic research, a violation of the very nature of economic data." In this case Keynes (see his 1939 attack on Tinbergen) was one of the more outspoken and influential counter-revolutionaries. He is not mentioned in Haavelmo's dissertation, but a small article (1943b) leaves no doubt against whom Haavelmo was arguing.

Before Haavelmo, the single most influential work on econometrics had probably been Frisch's (1934) "Statistical Confluence Analysis by Means of Complete Regression Systems,"[1] where Frisch had raised many of the problems on which Haavelmo came to work. It is worth noting that even though Frisch was well-acquainted with the calculus of probability (he had written his dissertation in the field), his analysis contains no probability models.[2] Instead of expounding the underlying theoretical basis, Frisch in the "confluence analysis" went directly to the set of data and wanted to "discover" which equations were "hidden" in them. Haavelmo, on the other hand, required researchers to start from an economic theory specified in the form of algebraic equations and probability laws. Data had to be interpreted in the light of a model specified in advance. In addition, the collection of data had to be guided by theory. An important task of the theorist was to describe how the variables were in principle to be measured.

One can still benefit from reading Haavelmo's "Probability Approach." Of course, modern textbooks contain more information on criteria for identification and on estimation methods, but they lack the basic discussion of methodology. In the words of Aldrich (1989, p. 26) it is, "though rarely recognised as

[1]Confluence analysis meant running all possible regressions between a set of variables. The philosophy behind it was that exact relations exist between economic variables. These are difficult to detect both because the variables are measured with error and because their range of variation is restricted by several relations at the same time. The purpose was to discover under what conditions one could still find out something about the relations, and it was shown that in certain cases coefficients from different regressions could be used to put bounds on the coefficients of the true underlying relations. Both Haavelmo and Koopmans wrote their first published works on confluence analysis, and the modern treatments of errors in variables and multicollinearity as well as the method of instrumental variable estimation (Reiersøl, 1941) can be traced back to confluence analysis. For further description, see Hendry and Morgan (1989) and Morgan (1990, ch. 7).

[2]Morgan (1990, p. 220 and p. 242) may give the impression that Frisch was a principled opponent of probability models. His skepticism in the 1930s (as his neglect of economic theory in the confluence analysis) to us seems more based on practical considerations about which research strategy would be most fruitful in the short run. It is evident from his report when Haavelmo was appointed professor that he fully accepted the probability approach as one auspicious way of proceeding, and this view is supported by the emphasis he put on probability theory in the curriculum for economics students in Oslo.

Table 1
Works by Trygve Haavelmo Cited in this Essay

"The Inadequacy of Testing Dynamic Theory by Comparing Theoretical Solutions and Observed Cycles," *Econometrica*, October 1940, *8*, 312–321.
"The Statistical Implications of a System of Simultaneous Equations," *Econometrica*, 1943a, *11*, 1–12.
"Statistical Testing of Business Cycle Theories," *Review of Economic Statistics*, 1943b, *25*, 13–18.
"The Probability Approach in Econometrics," *Econometrica Supplement*, July 1944, *12*, 1–115.
"Multiplier Effects of a Balanced Budget," *Econometrica*, 1945, *13*, 311–318.
"Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations," (with M. A. Girschick), *Econometrica*, 1947a, *15*, 79–110.
"Methods of Measuring the Marginal Propensity to Consume," *Journal of the American Statistical Association*, 1947b, *42*, 105–122.
"On the Notion of Involuntary Economic Decisions," *Econometrica*, January 1950, *18*, 1–8.
"The Concepts of Modern Theories of Inflation" (in Norwegian), *Ekonomiskt Tidsskrift*, 1951.
A Study in the Theory of Economic Evolution. Amsterdam: North-Holland, 1954.
"The Role of the Econometrician in the Advancement of Economic Theory," *Econometrica*, July 1958, *26*, 351–357.
A Study in the Theory of Investment. Chicago: University of Chicago Press, 1960.
"Business Cycles II: Mathematical Models," *International Encyclopedia of the Social Sciences*. New York: Macmillan and The Free Press, 1968.
Variation on a Theme by Gossen (in Norwegian). Oslo: Institute of Economics, 1972.
"What Can Static Equilibrium Models Tell Us?" *Economic Inquiry*, 1974, *12*, 27–34.
"Econometrics and the Welfare State," *Les Prix Nobel*. Stockholm: The Nobel Foundation, 1990, pp. 283–289.
"Bibliography of Trygve Haavelmo's Publications 1938–1987," *Scandinavian Journal of Economics*, 1990, *2*, 25–30.

such, one of the masterpieces of twentieth century methodological writing in economics."[3]

In particular, Haavelmo deserves to be remembered for his insistence that one should search for relations with as high a degree of autonomy as possible. Loosely speaking, a relation is more autonomous the wider is the range of circumstances under which the relationship is valid. A preference function is more autonomous than a demand function, because the demand function will break down whenever the preference function breaks down, and in addition it will break down in a number of other circumstances—for example, if the consumer is no longer a price taker in one market. An equation can never have a higher degree of autonomy than the equations it is derived from. The reason for wanting autonomous equations is that economists want to answer questions about the effects of changes in behavior, policy, institutions, and so on. The estimated relations would be of no help if they were just a mix of scores of other relations, and thus would break down for small changes in the environment. If Haavelmo's prescriptions had been followed, the now famous Lucas (1976)

[3]Stigum (1990) draws heavily on Haavelmo's insights in an attempt to provide more solid methodological foundations for both econometrics and economic theory.

critique—that a Phillips curve estimated under one policy regime would break down if the government changed to another policy rule—might not have been necessary. The Lucas critique is a special case of Haavelmo's criticism of making policy simulations with relations that do not possess the required degree of autonomy.

Haavelmo's contributions on simultaneous equations are contained mainly in the latter part of his dissertation and in two *Econometrica* articles (1943a), (1947a) and one article in *JASA* (1947b), which can still be read as examples of how to conduct inference in simultaneous equations. Economic statisticians attempting to estimate demand curves had groped with what is now known as the simultaneity problem since around 1910 (Morgan (1990), Epstein (1987) and de Marchi and Gilbert (1989) offer historical accounts). To estimate demand elasticities, regressions were run between quantity and price of a commodity. The results were sometimes strange, and it was realized that the regression between price and quantity might represent a supply curve as well as a demand curve. Various suggestions were made as to under what circumstances the regression line would represent supply or demand. An additional problem was that regression analysis yielded different elasticities depending on whether price or quantity was used as the variable on the left-hand side. In the 1930s it was realized that the same type of problems were inherent in statistical analyses of business cycles, and indeed in all cases where economic variables were determined by several relations at the same time. Frisch's confluence analysis was an attempt to come to grips with this problem.

It was Haavelmo's work which made common the distinction between the structural form and the reduced form of a model, the first being the equations as they are given to us from economic theory, and the latter the equations we get when we solve for the endogenous variables as functions of the exogenous variables and the stochastic disturbances. All information which data can possibly give on the model will be contained in the reduced form, or, as Haavelmo said, the most we can hope to learn from data is the conditional distribution of the endogenous variables given the exogenous variables. However, whether it is for testing theories or for predicting the effects of policy changes, we are often interested not in the parameters of the reduced form (or the conditional distribution) but in the parameters of the more autonomous structural equations.

The identification problem is the problem of whether, given full knowledge of the conditional distribution of the endogenous variables, it is possible to deduce what the structural parameter(s) of interest are. Haavelmo was the first to give this general and precise formulation of the problem. He showed that in a simultaneous equation system it was only possible to identify the structural parameters if we had put a priori (theoretical) restrictions on the structural equations; for example, assuming that certain variables did not enter certain equations, and he derived a determinant condition for identifiability. He also showed that even if all parameters in a structural equation were identified, least

squares estimation applied directly to the structural equation would give biased estimates, and he derived expressions for the size of the bias. This demonstration had an enormous influence on the Cowles Commission's later work on estimation methods in simultaneous equations.

Haavelmo's preferred method of estimation was apparently full information maximum likelihood; maximize the joint likelihood of all the endogenous variables taking account of all a priori restrictions following from the chosen economic theory. In his work with Girschick (1947a) he also used the method of indirect least squares, which consists in estimating the reduced form by ordinary least squares and then make inferences from that to the parameters in the structural form. He also showed how the Neyman-Pearson theory of testing could be used to test between different economic theories within the simultaneous equation framework.

In the words of Morgan (1990, p. 259), who has written the most comprehensive history of early econometrics, "Haavelmo's 1944 paper marks the end of the formative years in econometrics and the beginning of its mature period." Haavelmo was part of a small and tightly knit group who led this transition and created econometrics as we know it today. Frisch wrote the program declarations and raised the questions. Tinbergen provoked the methodological discussions by practising econometrics in his business cycle studies (1939). Haavelmo received strong influences from both, as well as from Jerzy Neyman and Abraham Wald. Tjalling Koopmans belonged to the same group as Haavelmo at Cowles, had earlier worked in close contact with both Frisch and Tinbergen, and argued for the use of probability models at the same time as Haavelmo. He later developed the criteria for identification and the concept of exogeneity in more detail (see in particular his contribution in Koopmans, 1950). It was Haavelmo, however, who gave the most general and comprehensive treatment of the new branch of economics. Again citing Morgan (1990, p. 259), "In his hands, the individual practical solutions and insights generated by the earlier work were finally fitted together as in a completed jigsaw puzzle, showing one single econometrics applicable to all branches of economics."

Although Haavelmo's main contribution was to econometric theory, he also did applied econometrics and published studies of the demand for milk in Norway, the market for pork in Denmark, share prices in Norway and the United States and the U.S. demand for food (see the bibliography in *Scandinavian Journal of Economics* [1990, pp. 25–30] for further references).

Of the early work the most interesting for today's readers is his *Econometrica* (1940) article, "The Inadequacy of Testing Dynamic Theory by Comparing Theoretical Solutions and Observed Cycles." Haavelmo criticized the view that a dynamic theory explaining business cycles should have a solution with oscillations. This was still a common opinion, held even by his teacher Frisch, in spite of Slutsky's (1927) demonstration that a moving average of independent random disturbances would appear to show cyclic behavior. (See Andvig, 1985 for an historical account.) Haavelmo proved that in a model where the deter-

ministic part converges smoothly without oscillations towards a stationary equilibrium, the observed time series will always appear to show cyclic behavior when stochastic shocks are properly taken account of. The article underlines his position in "The Probability Approach" that it is important to include stochastic elements in the economic models right from the outset, not just add them after the deterministic part of the model has been solved. The article can also be read as a warning against uncritical trend fitting and uncritical use of periods and amplitudes of observed cycles for drawing inferences about the structure of the underlying economic model.

In his later works on economic theory, one also finds many cases where Haavelmo formulates macro models as stochastic difference equations. In one of his theoretical books he uses a whole chapter to make excuses for why a particular model is non-stochastic. One may wonder why stochastic difference equations, so prominent in the writings of several leading economists in the 1930s and 1940s, almost disappeared from macroeconomic theory for a couple of decades, before gaining the central place they have now.

Why did Haavelmo move from econometrics to economic theory? He gave his reasons in his presidential address to the Econometric Society in 1957 (Haavelmo, 1958). Theory badly needed to be improved, and econometrics could help in doing so. There may also have been an immediate practical reason. In Oslo, Haavelmo came to a department overcrowded with students. The concern with reconstruction had made economics the first choice of many students. At the same time, the teaching of economic theory in Oslo badly needed improvement. Others could teach econometrics. His first book in economic theory was devoted to long-run growth problems.

Rich and Poor Countries

Haavelmo's 1954 book, *A Study in the Theory of Economic Evolution*, is remarkable in many senses. It is full of fruitful ideas and viewed from today, it is surprisingly modern in its approach. In several respects the book precedes more recent advances in economics such as the integration of accumulated human skills in growth models, the analysis of strategic behavior in international affairs, and the economics of rent-seeking behavior. All this is contained in a short book, only 114 pages long.

The book focuses on the most striking feature of the world economy, namely the economic dissimilarities between regions. Why are some regions "backward" while others are "advanced"? There are regions where income per head has tripled over a century, while other regions have had almost no growth at all. Haavelmo wished to explain these dissimilarities between regions without assuming that people in various parts of the world were different from the outset. Which explanations could then remain? He attacked this question in a purely theoretical way with a focus on macro dynamic methods and on the merits of different types of explanations from a methodological point of view.

The connections to his work in econometrics are only indirect. There is an introductory remark that the possibilities for econometric testing are more promising when one goes from short-run equilibria to more easily detectable differences in the long-run developments. Moreover, part IV deals with stochastic specifications of dynamic macro models. However, no finite conclusions are offered why some countries are richer than others. Such conclusions can only be obtained from econometric studies for which he wished to provide the theoretical foundation. In fact, the book does not contain any numbers at all.

Most of the models in the first parts of the book contain three building blocks: a macro production function where total production depends on labor, capital and the general level of skills and know-how; accumulation equations that explain how the growth of capital, skills and know-how depends on economic variables; a "law" of population relating the number of births and deaths to economic factors.

Numerous model experiments are performed. The first one is inspired by the classical economists. The real wage equals the marginal product of labor. All wage incomes are consumed, while profits and land-rents are invested. Decreasing returns to scale then lead to a growth path with a decreasing profit rate over time. The living conditions of workers may rise or stagnate depending on how strongly population growth reacts to improving living standards. If population growth reacts strongly to higher incomes, the laboring class remains on the subsistence level. If population growth reacts less, however, the model predicts an increasing real wage. This race between population growth and economic progress appeared in many later works and lectures by Haavelmo.

Together with the more verbal analysis by Wicksell (1934) and the mathematical models by Frisch (1940), Tinbergen (1942) and Ramsey (1928) (neglected by most researchers until the 1960s), Haavelmo's growth approach precedes the standard textbook model by Solow. Both Haavelmo and Solow (1956) used a simple saving function and a production function with substitution possibilities between capital and labor. Both consider exogeneous as well as endogenous population growth and explore extensions with variable saving ratios. Haavelmo formulated (in Ch. 9) a much more general model than Solow's, but he did not solve it. Instead he studied various special cases (in Ch. 5–8) that are chosen such that explicit solutions can be found. Some of these exercises are similar to Solow's, but far from all of them.

What was later to become the standard neoclassical growth model provides an inadequate framework for Haavelmo's problems. As Stiglitz (1987) and others have worried about, standard theory predicts convergence of growth rates if all countries have access to the same technology. Most of Haavelmo's models, however, are not stationary in per capita terms. In addition, growth rates may differ due to endogenous accumulation of human skills.

Haavelmo explores the influence from accumulated knowledge upon production, and the influence from capital accumulation upon the growth of education and know-how. There is an interesting link between these model

experiments and "the modern growth theory" (Romer, 1986; Lucas, 1988) in the insistence on the role of accumulated human skills in the growth process.

Among other things, Haavelmo demonstrated how small differences—for instance in the savings rate—with a negligible impact on short-run welfare, may give rise to significant differences in the long run (since his models are not stationary in per capita terms). The tyranny of such small decisions may therefore make some countries rich and others poor. Haavelmo also pays more attention to the initial conditions than is usual in more recent growth analysis (except in chaos theory). Within some of his models, positive growth requires an initial income per capita above a critical level. In these cases, small differences at the starting points may lead to divergent developments. In his more complicated models the initial conditions determine whether the solutions are stable or not. Finally, drastic changes caused (for instance) by droughts, floods and diseases are more important in some countries than in others. This is captured by incorporating stochastic shocks in the dynamic equations. Haavelmo is then able to derive both the expected growth path and the variance in the growth pattern caused by accumulated shocks and shifts in the moving "initial" conditions. The higher the variance, the more likely is it that severe income gaps will develop between countries as time goes by.

A Study in the Theory of Economic Evolution also offers an interesting discussion of conflict and cooperation between countries. In part V of the book a game-theoretic model of international economic relations is presented. The main idea is that each country can employ its resources productively or in attempts to influence the distribution of income between countries. Types of unproductive spending that fit into Haavelmo's model description may be everything from hiring tough trade negotiators to military spending and gunboat diplomacy. Such use of resources reduces the total size of the cake produced by all countries together. Yet this action may very well be profitable as long as the country improves its share. If other countries employ all their resources productively, it becomes particularly profitable for one country to allocate some resources to affect the international distribution. But when it is profitable for one country to do so, it is profitable for all countries and in the non-cooperative equilibrium each country allocates its resources such that the marginal income on all activities within the country is identical. Hence, a free-for-all system may be very unlike a perfectly functioning free trade regime.

Haavelmo's model may provide micro foundations for the political economy of unequal exchange in international trade, so often emphasized by radical economists. The model is also somewhat related to the policy analysis of strategic trade, a topic widely discussed in the past decade. Haavelmo did not, however, have a specific model of monopolistic competition in international trade. Haavelmo's analysis is also related to the recent literature on rent-seeking following Ann Krueger's contribution in 1974. The basic principle is the same: Improving one's position to capture rents will often involve a waste of resources. In Haavelmo's book the game is between countries rather than

between interest groups and government. He had discussed other forms of unproductive work or rent-seeking in his (mimeographed) lectures in the late 1940s, where he considered "elbowing activities" and commercial advertising as examples.

In the final part of the book, one section is called "Fragments of a Theory of Migration." Here it is explained why income gaps between regions may persist and sometimes become wider even when labor migration is unrestricted. The model-sketches in this area are complementary to the standard Harris-Todaro (1970) framework where migration equalizes *expected* incomes rather than incomes, with the unemployment as an equilibrating factor. Haavelmo (p. 102) focused more on the heterogeneity of workers due to differences in human capital: "The important facts are what the emigrants think they can achieve in the new region, when they bring with them their own level of skill and knowledge." Accordingly, with heterogenous human capital and regional differences in opportunities (created by population pressure, the level of accumulated know-how and so on), it is possible to have migrations in two opposite directions simultaneously, and skilled people may move to rich countries and fuel their economic progress further.

Related to the themes of *A Study in the Theory of Economic Evolution* is Haavelmo's early concern, in the 1960s and 1970s, for environmental problems and the long run consequences of pollution. His works in this area have mainly appeared in Norwegian, but they have inspired internationally published research in the field (Hoel, 1978; Førsund and Strøm, 1988). Haavelmo's basic approach is one where the utility functions of consumers include both produced commodities and variables that represent the quality of the environment. While produced commodities are represented by flows per unit of time, the environment is affected by the accumulated stocks of pollution emissions from production and consumption activities (like carbon dioxide emissions). Thus, each consumer faces a tradeoff between the immediate pleasure related to higher consumption and the eternal pain from the extra pollution it generates. Obvious free-rider problems exist, since consumption is a private good while pollution is a public bad. Hence, unguarded development may become extremely harmful.

The Theory of Investment and Its Critics

Haavelmo's interest in the theory of investment can be traced back to the 1940s, when he published a couple of short articles on the topic. It has continued to occupy him since then. Since his early contributions were motivated by problems with Tinbergen's estimated investment functions, this is probably one of the areas where he felt that econometrics had revealed that theory needed to be improved.

A Study in the Theory of Investment (1960) is a grand treatise in the old style. It takes the reader through an exhaustive range of topics within the theory of capital, starting from the fundamental contributions by Bøhm-Bawerk and Wicksell. In ten chapters it goes through the various roles of time in the process of production. Examples of key words for these chapters are: "The pure aging process," "The continuous assembly line," and "The production of large units." After that comes a long section on optimal growth and optimal durability of capital, and then the final and most interesting section on investment in a market economy. This section is also broad in scope, covering micro aspects, general equilibrium, macroeconomic disequilibrium, and various side issues like the choice of durability. All this is done in about 200 pages, which means that the treatment of each question is rather brief.

The book attracted both attention and criticism when it came out. In our opinion, the critics misunderstood or overlooked the main arguments. This was perhaps understandable, considering the wealth of material in the book. Our own understanding has benefitted greatly from the notes from Haavelmo's lectures in the 1950s, and it is a pity that these were not published as articles in English.

The main purpose of the book was to destroy the standard Keynesian demand function for investment, where net investment is a simple function of the rate of interest, and to offer an alternative. Other major concerns in the book are to explain why net investments are so volatile, and why they are almost always positive. The attack on the simple investment demand function takes many forms, but the most fundamental is this: Assume a model of an optimizing firm in continuous time. Assume an exogenously given sequence of product and factor prices and of interest rates. Then, provided some technical assumptions are satisfied, there exists an optimal level of the present stock of capital. This is either equal to or different from the stock of capital which the firm inherited from the past.

Under the given assumptions, the firm will immediately adjust the stock of capital to the new optimal level. Investment is the rate of change in the stock of capital per unit of time. At the initial moment the stock of capital either makes a finite jump, or it stays constant. In the first case the rate of change of the stock per unit of time is infinite, otherwise it is zero. Thus standard investment demand functions cannot be derived within this framework. If there is a finite change in the rate of interest, the demand for capital makes a jump. Investment demand at that moment is *not defined*, and it is not justified to write it as a continuous function of the level of the interest rate.

There is one exception to the statement that optimal investment will be either zero or infinite. If the capital stock is initially in equilibrium and prices and interest rates change continuously, then in the neoclassical setting the rate of change of the capital stock will be finite and different from zero in general. This case is discussed in Chapter 29, Section I of Haavelmo's book. The special case may often be relevant for economic theory, as in models of equilibrium

growth. But it is clearly not relevant in macro-theory for answering a question like: what happens if the monetary authority lowers the interest rate by two percentage points now?

Among the critics were Jorgenson (1967) and Sandmo (1971). The critics claimed that Haavelmo was wrong, and that one actually could derive a finite investment demand function in the above setting. Jorgenson accepted Haavelmo's main argument, but then begged the question by drawing attention to one of the special cases where prices change continuously. Instead of asking simply what happens to investment when the rate of interest is raised ceteris paribus, Jorgenson asked what happens to investment when the rate of interest increases together with all future prices of capital goods and in such a way that the present rental price for capital is unaffected.

Sandmo blurred the argument by changing to discrete time. In discrete time, if the stock of capital in two subsequent periods is finite, the rate of change of capital per period is finite too. This also begs the question. The discrete-time model says that the capital stock will be adjusted to the new optimal level "as soon as possible." By the arbitrary assumption of the investigator, "as soon as possible" is exactly one period (of unspecified length). As long as one does not have a theory of what determines the length of the time period, one has not explained what determines how fast the capital stock adjusts.

Haavelmo's main constructive contribution to the macro theory of investment is a two-sector model where at any point in time, the stock of real capital is given from the past. Capital can be traded between firms, and the price of existing capital goods clears the capital market. This price is also the price of new capital supplied by the investment goods industry. The level of investment is then determined by the intersection of this price with the increasing supply curve of that industry. In other words, the level of real investment is determined by the relationship between the price of existing capital goods and the factor costs and technological efficiency involved in producing new capital.[4]

The reader may have noticed the similarity to Tobin's (1969, section 5) q-theory of investment: "The rate of investment... should be related... to q, the value of capital relative to its replacement costs." The difference is that Tobin seems to have had a one-sector model in mind, so that he could not equate the prices of new and existing capital goods. Later, Hayashi (1982) rationalized Tobin's formulation by assuming increasing adjustment costs within each firm. In Haavelmo's main model the adjustment costs are instead at the macro level, but he also presented models with adjustment costs at the firm level.

In the "Theory of Investment," the original question of "Why is investment so volatile?" is changed after the thorough neoclassical analysis of investment demand to a question of "Why is investment not even more volatile?" The

[4]A similar set-up is used in Uzawa's (1961) two-sector growth model. A common inspiration seems to have been Wicksell (1934).

answer is found in the supply of investment goods. The message to the practicing econometrician becomes that he should drop the simple demand function for investment, work with demand functions for capital properly grounded in theory and pay more attention to the supply side. Haavelmo claimed that his two-sector model was closer to what Keynes actually had meant in the *General Theory* than the standard Keynesian investment function. Le Roy (1983) argues that a two-sector model with sector-specific capital would be even closer.

Equilibrium and Disequilibrium

In his later books (in Norwegian) Haavelmo spends much space on discussing the basic concepts of economics, like resources, preferences, equilibrium, and the relationship between micro and macro. One area where his contributions deserve more attention is disequilibrium theory.

In a critique of Bent Hansen's (1951) dissertation on inflation theory in 1951, Haavelmo pointed out that outside of equilibrium, the presumptions behind the ordinary demand and supply curves do not hold. Agents face different constraints and make different choices. It is thus questionable whether what has since been labeled the notional demand and supply curves are at all relevant for the dynamics of prices outside of equilibrium.

The argument against traditional price dynamics was followed up by a small article "What can static equilibrium models tell us?" in 1958 (translated into English by Leijonhufvud in 1974). There Haavelmo discusses the defects of equilibrium theory, and calls for a game theoretic treatment of markets with many buyers and sellers. In dynamic price theory one should be explicit about *who* sets the price, and one should take account of the constraints agents actually face when they are outside the competitive equilibrium.[5]

Unfortunately, Haavelmo did not himself develop price theory along these lines. In his writings, however, there are many examples of disequilibrium models where he discusses different regimes. In *The Theory of Investment*, Chapter 33 is devoted to a case where the monetary authority pegs the interest rate at a level different from the equilibrium rate. So far, Haavelmo follows Wicksell. The innovation is that he considers carefully the different constraints that firms will face depending on whether the rate of interest is at, below or above Wicksell's natural rate. As Haavelmo commented in *The Theory of Investment*, "it could indeed be a fascinating research project" to proceed with a study of disequilibrium regimes.

English readers can find another example of his treatment of disequilibrium in his 1968 article on "business cycles" in *Encyclopedia of the Social Sciences*. Depending on the exogenous interest rate, and other initial conditions, there

[5]A related critique was formulated by Arrow (1959).

are two possible regimes with different constraints. In regime 1 the marginal productivity of capital is above the user cost and firms expand their capital stocks. Total demand is unlimited since firms want to increase their amount of capital as fast as possible. Hence, production is capacity-constrained and grows along the full employment path. As more capital is accumulated, however, the marginal productivity of capital gradually falls towards the user cost. When capital finally reaches its optimum level in regime 1, investment demand drops to zero. This gives rise to regime 2, where production is demand-constrained. Firms discover they have, in fact, too much capital and too many workers. There is Keynesian unemployment until the amount of capital has depreciated so much that its marginal productivity equals its user cost. Then firms again want to invest and the economy immediately switches to regime 1 and a new upswing starts. In this way the model gives rise to endogenous cycles.[6]

Finally, in connection with macro economic disequilibrium we cannot avoid mentioning Haavelmo's (1945) article on the balanced budget multiplier, also labelled "Haavelmo's theorem" in many textbooks. From his references it is evident, however, that the theorem was common knowledge by then. That should not surprise anybody, since the theorem is clearly stated in Chapter 31 of Ricardo's *Principles*.[7] Yet, as Haavelmo's introduction shows, there was still some confusion about the balanced budget multiplier, and his clear exposition and mathematical proof made his article a standard reading on the subject for two decades.

Preferences, Democracy and Welfare

On several occasions Haavelmo presented his views on the problems of evaluating economic systems. The approach is exploratory and provocative. Most of these writings are in Norwegian, but an early example is published in English in 1950, under the title, "On the Notion of Involuntary Economic Decisions." One main idea is that people have preferences not only over economic outcomes, but also over the way the economy is organized. Here, as in other connections, Haavelmo insisted on respecting people's preferences regarding things other than consumption goods, even if they seem odd to an economist.

A more recent work along similar lines is called "Variations on a Theme by Gossen" (1972, 100 pages in Norwegian). The discussion is motivated by a belief that the tools and models used in economics may be fruitfully applied beyond the range of problems usually considered by economists. One may get a

[6]Haavelmo's discussion of the role of effective demand in different regimes both in his investment book (1960) and elsewhere is somewhat related to more recent advances as Solow and Stiglitz's (1968) theory of aggregate employment and production in the short run, and Barro and Grossman's (1971) disequilibrium model.

[7]As pointed out by Haavelmo's friend and colleague from Aarhus, Jørgen Gelting (1941).

flavor of Haavelmo's reflections by just listing the headlines: the production of opinions (endogenous preference formation, moral codes, false preferences and real needs); tolerance or power balance; majority voting as a system of government; justice, pleasure and efficiency in the welfare state.

Between the lines one may read a warning against wishful thinking about the ease of designing better systems. First, the comparison of welfare between difference systems is complicated by the fact that preferences often are endogenous. Second, the mechanisms of conflict resolution are seen to be important for evaluation of alternative political and economic systems and their stability. Third, the rules of the game that make up a society are not given once and for all.

As Haavelmo put it in his Nobel lecture (1990): "...the results of the individuals in a society responding in a certain way to the original rules of the game have a feedback effect upon these rules themselves." When explaining and evaluating economic systems, economists should, according to Haavelmo, pay more attention to this interaction and rely less on reasoning which starts from the fictitious state of nature where every individual is alone. Society conditions behavior in ways that we are apt to overlook if models are built simply by aggregating the behavioral responses from individuals in isolation.

The Teacher

When Haavelmo began teaching in Oslo, his lectures on welfare economics and general equilibrium must have been a welcome break from Frisch's on the advantages of central planning and the latest news in mathematical programming. As a lecturer Haavelmo was unique. He never repeated old lectures, but gave a new topic every semester. His way of communicating made him *the* teacher of two generations of Norwegian economists. He often started his lectures with startling statements, like "Why should anybody by happy when more jobs are created?" or "Does machinery deprive workers of their living?"

The lectures were normally recorded by students, then checked by Haavelmo and published. In that way the students got "lectures" on statistical theory, econometrics, welfare economics, inflation, employment, growth, the role of expectations, international trade, income distribution, business cycles and a host of other topics, even if there were not enough teachers available to cover these subjects at the same time. Often the lectures sound critical towards received theory, but Haavelmo took care to stress that received theory was in most cases far better than no theory. Sometimes the lectures contained contributions which were later included in the books.

In fact, the books were addressed more and more to his students as the years went by. The change from English to Norwegian language could have to do with this. Haavelmo did not seek personal recognition, and the important thing for him more and more seemed to be to encourage his students to do their own thinking. In the later lecture notes, Haavelmo's words are supple-

mented with contributions from his students; something which is not necessarily an advantage to present readers.

If it had been left entirely to Haavelmo, even less might have been published. One of us once edited a Norwegian journal of economics, and remembers being called to the office of professor Leif Johansen, one of Haavelmo's favorite students, to be told that Haavelmo had written "something very interesting," and that "you have to get hold of it and convince him to publish it." Most of Haavelmo's articles in later years were solicited in one way or another.

Haavelmo had an enormous influence on the small Norwegian society through his students during the 30 years he was a professor in Oslo. Since the early 1960s, every Norwegian cabinet has had at least one member who was once a student of Haavelmo. At one time the non-political administrative heads of a majority of the ministries were his former students.

As a lecturer, researcher and writer Haavelmo is often inspired by everyday problems, but the approach he takes always turns from these to more fundamental questions of lasting importance. He is celebrated as one of the founders of modern econometrics. Moreover, he was among the first to develop a consistent theory of investment. In addition to these path-breaking publications he has many original contributions on various aspects of macrodynamics, disequilibrium regimes, rent-seeking activities, environmental issues and several methodological questions. Many of the ideas in his writings on economic theory were developed further in scientific contributions by his students. There are more ideas to work on.

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References

Andvig, Jens Chr., "Ragnar Frisch and the Great Depression," *Norwegian Institute of International Affairs*, Oslo, 1985. (Forthcoming, Cambridge University Press.)

Aldrich, John, "Autonomy," *Oxford Economic Papers*, 1989, *41*, 15–34.

Arrow, Kenneth, "Toward a Theory of Price Adjustment." In Abramowitz, Moses, et al., eds., *The Allocation of Economic Resources*. Stanford: Stanford University Press, 1959, pp. 41–51.

Barro, R. H., and H. I. Grossman, "A General Disequilibrium Model of Income and Employment," *American Economic Review*, 1971, *61*, 82–93.

Epstein, Roy J., *A History of Econometrics*. Amsterdam: North-Holland, 1987.

Frisch, Ragnar, *Statistical Confluence Analysis by Means of Complete Regression Systems*. Oslo: University Institute of Economics, 1934.

Frisch, Ragnar, "Befolkningsoptimum," *Statsokonomisk Tidsskrift*, 1940, *5–6*, 157–219.

Førsund, Finn, and Steinar Strøm, *Environmental Economics and Management: Pollution and Natural Resources*. London: Croom Helm, 1988.

Gelting, Jørgen, "Nogle bemerkninger om finansieringen av offentlig virksomhed," ("Some Remarks on Financing Public Activities"), *Nationaløkonomisk Tidsskrift*, 1941, *79*, 293–299.

Hansen, Bent, *A Study in the Theory of Inflation*. London: George Allen & Unwin, 1951.

Harris, J., and M. Todaro, "Migration, Unemployment and Development: A Two Sector Analysis," *American Economic Review*, 1970, *60*, 126–138.

▶**Hayashi, Fumio,** "Tobin's Marginal *q* and Average *q*: A Neoclassical Interpretation," *Econometrica*, 1982, *50*, 213–224.

▶**Hendry, David, and Mary Morgan,** "A Reanalysis of Confluence Analysis," *Oxford Economic Papers*, 1989, *41*, 35–52.

Hoel, Michael, "Resource Extraction and Recycling with Environmental Costs," *Journal of Environmental Economics and Management*, 1978, *5*, 220–35.

Jorgenson, Dale W., "The Theory of Investment Behavior." In Ferber, R., ed., *Determinants of Investment Behavior*. New York: Columbia University Press, 1967.

▶**Keynes, John M.,** "Professor Tinbergen's Method," *Economic Journal* 1939, *49*, 558–68.

Koopmans, Tjalling C., ed., "Statistical Inference in Dynamic Economic Models," *Cowles Commission Monograph* 10. New York: Wiley, 1950.

Krueger, Anne O., "The Political Economy of the Rent-Seeking Society," *American Economic Review*, June 1974, *64*, 291–303.

▶**Le Roy, Stephen S.,** "Keynes' Theory of Investment" *History of Political Economy*, 1983, *15*, 397–421.

Lucas, Robert E. Jr., "Econometric Policy Analysis: A Critique." In Brunner, Karl, and Allan Meltzer, *The Phillips Curve and Labour Markets*. Amsterdam: North-Holland, 1976.

▶**Lucas, Robert E. Jr.,** "On the Mechanics of Economic Development," *Journal of Monetary Economics*, 1988, *22*, 3–42.

Marchi, Neil de, and Christopher Gilbert, eds., "Special Issue on History and Methodology of Econometrics," *Oxford Economic Papers*, 1989, *41*.

Morgan, Mary, *The History of Econometric Ideas*. Cambridge: Cambridge University Press, 1990.

▶**Ramsey, F. P.,** "A Mathematical Theory of Savings," *Economic Journal*, 1928, *38*, 543–59.

▶**Reiersøl, O.,** "Confluence Analysis by Means of Lag Moments and Other Methods of Confluence Analysis," *Econometrica* 1941, *9*, 1–24.

▶**Romer, Paul M.,** "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, 1986, *94*, 1002–37.

▶**Sandmo, Agnar,** "Investment and the Rate of Interest," *Journal of Political Economy*, 1971, *79*, 1335–45.

Slutsky, E. E., "The Summation of Random Causes as the Source of Cyclic Processes," *The Problems of Economic Conditions*. Moscow: The Conjuncture Institute, 1927, *3*, no. 1, 34–64.

▶**Solow, Robert,** "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 1956, *70*, 65–94.

▶**Solow, Robert, and Joseph Stiglitz,** "Output, Employment and Wages in the Short Run," *Quarterly Journal of Economics*, 1968, *82*, 537–60.

Schumpeter, Joseph A., *History of Economic Analysis*. London: George Allen and Unwin Ltd., 1954.

Stigum, Bernt, *Toward a Formal Theory of Economics*. Cambridge: MIT Press, 1990.

Stiglitz, Joseph E., "Learning to Learn: Localized Learning and Technological Progress." In Dasgupta, Partha, and P. Stoneman, eds., *Economic Policy and Technological Performance*. Cambridge: Centre for Economic Policy Research, Cambridge University Press, 1987, pp. 125–153.

Tinbergen, Jan, *Statistical Testing of Business Cycle Theories*, 2 volumes. Geneva: League of Nations, 1939.

Tinbergen, Jan, "Zur Theorie der langfristigen Entwicklung," *Weltwirtschaftliches Archiv*, 1942, *LV*.

▶**Tobin, James,** "A General Equilibrium Approach to Monetary Theory," *Journal of Money, Credit and Banking*, Feb. 1969, *1*, 15–29.

▶**Uzawa, Hirofumi,** "On a Two-Sector Model of Economic Growth," *Review of Economic Studies*, 1961, *29*, 40–47.

Wicksell, Knut, *Lectures on Political Economy*, Vol. I and II. London: George Routledge and Sons, Ltd., 1934.

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