

Mind, Market and Society

Network Structures in the Work of F. A. Hayek

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How markets emerge, function, and remain in existence (or are reproduced) are problems that economists have hardly addressed. One of the exceptions is Friedrich Hayek. Between the second half of the 1930s and the early 1960s he formulated a number of ideas about these topics. Historically, these were inspired by his very early work on cognitive psychology, which in the 1950s was one of the sources of neural network models. Among the features that found their way from his cognitive psychology into his market models are the distributed nature of knowledge in a system and its coordination by means of a self organizing process. Systematically, Hayek's ideas on markets and competition are part of his larger research programme in economics. This programme aimed at developing a theory of disequilibrium growth in an intertemporal general equilibrium framework. Hayek's writings do not constitute a systematic theory of dynamic market phenomena. However, they contain a number of insights that have hardly been noticed. With hindsight, we may observe that these ideas are part of what sociologists would call a network model. The main characteristics of such models are described. Some recent applications of sociological network theory to market phenomena, notably by Harrison White and Ronald Burt, are very much in the spirit of Hayek, without being influenced by him. The same is the case within economics, where network approaches are much rarer. The economists Alan Kirman and Robert Gilles have indicated ways to develop network models for understanding markets. Like Hayek's ideas, these are extensions of a general equilibrium approach. An economist who was inspired by Hayek but who does not explicitly present his analysis as a network model is George Richardson. The works mentioned have not been integrated, and together they cover the problems of the emergence, functioning and reproduction of markets in a very gappy way.

It is argued that Hayek's later work in evolutionary social theory may be used to make progress. The first appendix summarizes Hayek's cognitive psychology, the second discusses some historical questions related to its influence on the rest of his work.

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1. Introduction.

The present state of our knowledge about the emergence, functioning and stability of markets is unsatisfactory. True, economists share some general beliefs about markets. In a system of private property, self-interested individuals will engage in exchanges that they find advantageous. The system of relative prices helps to find the best deal possible. Arbitrage and competition make prices of the same good converge. However, these are little more than plausible ideas and they do not amount to a theory explaining the dynamics of the emergence and the functioning of markets nor their stability, that is, their reproduction in time. The microeconomic models used are basically static, and they state the conditions under which certain market forms exist. They tell us next to nothing about the dynamics of markets: how they come into being, how they work, how they reproduce themselves, how prices are set, and what the mechanism of competition is. Recently, laboratory studies into the characteristics of certain markets have been started, interest in historical research has been revived, and the most recent addition to the study of markets are simulation studies. Nevertheless, we are still very far from understanding markets.

An early critic of the unsatisfactory state of microeconomics is Friedrich Hayek. In 1937 he published "Economics and knowledge", followed by a series of articles addressing questions related to the functioning of markets and competition. To his criticism he added a positive contribution. And although these publications by no means present a complete and coherent theory, they contain valuable insights into the problem. I will argue that Hayek's ideas about markets and competition can be understood as an early effort to develop what contemporary sociologists would call a network model. Recent applications of network models to economics, and more in particular to markets and competition, can be seen as intellectual descendants of some of the ideas that Hayek formulated. However, they do not exhaust the potential of Hayek's insights.

Hayek's theory of markets and competition builds upon his earlier work in economics. It is

an elaboration of the concept of equilibrium which he developed early in his career. Therefore I will start with a discussion of this early work.

2. Hayek's economics.

Hayek's earliest interest in economics lie in the field of monetary theory and the theory of imputation. Hayek spent a year and a half in the United States. During his stay, in 1923, he drafted an outline for a Ph.D.-thesis, to be submitted at New York University. Its title is "Is the function of money consistent with an artificial stabilization of its purchasing power?" The thesis was to have concentrated largely on monetary theory. Only the last chapter was to be devoted to business cycles. The thesis was never written. Hayek went on to publish two articles on monetary policy and stabilization under the gold standard (Hayek 1924 and 1925), one on the problem of imputation (Hayek 1926), an obituary of Wieser (Hayek 1926a) and an article on the interest rate (Hayek 1927). He then published a lengthy article on general equilibrium theory (Hayek 1928). Its introduction states that the article is intended as part of a major work on the objectives of monetary policy (a work which was also not realized¹), and the last nineteen pages are devoted to a discussion of the influence of the monetary system on the economy and of the general price level. While this second part is innovative, the first twenty-five pages are revolutionary. There Hayek develops the first systematic intertemporal general equilibrium theory in the history of economics.² He develops his theory in two stages. The first thirteen pages discuss a barter economy, the next twelve a monetary one.

Hayek poses himself the task of examining "the necessity and significance of relative levels of prices at successive points in time" (Hayek 1984: 72).³ This might suggest that his analysis is a static one. Such an impression could not be wider of the mark. A discussion of the concept of equilibrium which Hayek uses in his article will make this clear. Hayek defines equilibrium for an individual. It is the state in which the data of the individual's economic plan correspond to his expectations (1928: 38-9). Every individual compares the actual level of the satisfaction of his needs with the desired one. In his evaluation he includes the means available to satisfy his needs. Time separates the actual state of affairs from the desired one. Hence every plan involves a time interval, and there is no plan without time. Just like physically identical goods may differ in value according to their different locations, there is no reason to assume that physically identical goods may not also differ in value according the different times at which they are wanted or become available. The received theory was Walras' general equilibrium theory, which deals with a system of prices of goods at the same moment of time. It is a theory about the system of synchronic relative prices, not about individuals who compare the value of goods at different moments of time. Yet nothing in the basic idea or the formalism of Walrasian general equilibrium theory prevents us from introducing goods whose only difference is their time index. Technically identical goods that differ only with respect to the place or time at which they are available are different goods from an economic point of view.⁴ So, synchronic general equilibrium theory is a special case of a diachronic general equilibrium theory (1928: 44-

¹What are apparently chapters of the projected book have only recently been published in the third volume of The Collected Works of Hayek (Bartley & Kresge 1991).

²Cp. also Milgate 1979. According to Hicks Knight generalized Pareto's theory in a similar way independently from Hayek. Cp. Hicks 1977: 138. Hicks refers to Knight 1921, ch. V. But there the extension of general equilibrium theory that Hicks ascribes to Knight is not stated explicitly and as such. As far as Knight generalized Pareto's theory into a diachronic theory at all, this was not presented as a remarkable step, neither by Knight himself ("There is little that is fundamentally new in this book", Knight 1921: ix), nor by Stigler, who wrote the preface to later options.

³ Hayek 1928 : 35.

⁴ The storing of a good transforms it into a different good. Cp. 1928: 43, and PTC: 79. The identification of a good raises a host of problems that will not be discussed here.

5).

The way in which Hayek defines equilibrium not only enables him to generalize general equilibrium theory into an intertemporal theory, it also provides the means for that theory to break away from a comparative-static or stationary-state context. Hayek defines equilibrium as a relation among actions. The actions of an individual follow one another in time. Hence, the concept of time is inherent to that of equilibrium. The introduction of a plan also means that equilibrium theory is not restricted to comparative statics or the stationary state. All economic activity is aimed at reaching a desired distribution of the satisfaction of needs through time, and this distribution may involve growth, shrinkage or constancy of the product. Whether individuals aim at a constant, a decreasing or an increasing level of satisfaction is all part of their plans, and which case obtains is an empirical matter. Notice that this idea is tantamount to the life-cycle and permanent-income hypotheses, which are now associated with the work of Duesenberry and Friedman.⁵ An individual planner remains in equilibrium if his expectations are not falsified, no matter whether he expects his income to grow, shrink or remain constant.

Thus, the analysis in relative diachronic prices is not restricted to the cases of a growing or a shrinking economy. It applies equally to a stationary economy. For in a stationary economy, too, there are continuous real changes, and hence changes in relative prices. Processes repeat themselves with a certain regularity, or are replaced by others, precisely in order to keep the system as a whole in a stationary state.⁶ The system of relative prices registers the deviations from the stationary state, and makes it possible for corrections to be made. An adaptable diachronic system of relative prices is a necessary condition for maintaining a stationary state. (This is consistent with Hayek's criticism of the use of the general price level to understand and remedy phenomena of (disequilibrium) growth. I will not go into this here.)

In the first part of the article Hayek restricts his analysis to an isolated individual ("Suppose, then, that for the time being we consider the evaluation as if it is undertaken by an isolated individual.", Hayek 1984: 77⁷). One of the problems one would expect Hayek to address subsequently is how the individual equilibria hang together or are co-ordinated. However, he does not go into this. When Hayek discusses exchange among several individuals (on p. 41), he only does so because he wants to analyze the influence of changing prices on individual equilibrium. Up to that point, his analysis was in terms of subjective values, and exchange transforms subjective values into prices. Hayek does not deal with the question how the tendency to intertemporal equilibrium which he assumes to exist is brought about. He simply assumes that exchange through the market takes care of that. He shows that a change in the intertemporal relative price of one (technically identical) good necessitates changes in relative prices elsewhere in the system. Diachronic and synchronic exchange relationships are interdependent. Another assumption Hayek makes throughout his 1928 article is that there is a complete system of futures markets. Obviously, this is an idealization.⁸

Next, he introduces monetary exchange, and goes more deeply into the details of his equilibrium concept. He discusses three types of expected change and their consequences:

"Such changes in data as are predictable, which can as such be taken account of in the economic

⁵Indeed, Hayek mentions "sein [the producer's] Gesamteinkommen in dem ganzen Zeitraum" (Hayek 1928: 55, that is: "his total income for the period as a whole.", Hayek 1984: 93). Desai mentions that the term "permanent income" appears in Hayek's "The Maintenance of Capital" of 1935. (Desai 1994: 31).

⁶ The obvious analogy with a stationary car engine captures this feature accurately. Another apt analogy is the human body in a state of apparent rest. When we stand still, our body rests on our legs. But in order to maintain this state of stationary equilibrium, literally hundreds of muscles and hundreds of thousands of nerves are involved in a process of continuous change.

⁷ Hayek 1928: 40.

⁸ In his subsequent work, the intertemporal allocation function of futures markets is taken over by changes in the structure of production. This is argued in detail in Birner forthcoming.

plan, and whose effects can therefore be handled with equilibrium analysis, can be divided essentially into three groups: those which recur with precise periodicity; those which are of uniform tendency in both direction and extent; and finally, those whose unique occurrence can be confidently expected for a definite period in time, as the result of developments which are currently observable or of known human decisions." (Hayek 1984: 84-5; in the original, Hayek 1928: 47)

So, Hayek discusses different types of expectations which are realized and their consequences for the system of intertemporal prices. The mechanism through which the adaptation of intertemporal prices takes place involves the falsification of expectations on the part of at least some individuals. This is all that is said about the co-ordination of the plans among different individuals. The rest of the article goes in detail into the consequences of a fractional reserve currency for the system of intertemporal prices. Hayek's conclusion is that any such monetary system disturbs adaptations in intertemporal prices ("the establishment of that natural structure of prices through time corresponding to the intertemporal exchange relations originating from barter [will be prevented by] any monetary system at all, either actually existing or merely conceivable.", Hayek 1984: 95⁹). Attempts to keep the general price level constant aggravate the problem: "[m]onetary policy which is aimed at keeping the value of money constant only makes the disturbing influence of money worse (ibid.). Monetary disturbances are the cause of disequilibrium growth. The business cycle itself consists of changes in the productive apparatus.¹⁰ In subsequent books and articles Hayek's elaborates this basic idea into a theory of the business cycle.¹¹

A crucial feature of Hayek's business cycle theory is that agents react to perceived prices, that is, money prices. A fractional reserve system acts as an amplifier for changes in real scarcities, which results in money prices failing to accurately reflect real relative scarcities. Investment decisions are taken on the basis of false price signals. By the time it is discovered that these are malinvestments, which is when the final products fail to match the unchanged demand of the consumers, the production structure has already been adapted. A return to a production structure which does correspond to real relative scarcities is a necessary and painful process. While the re-adaptation of the production structure after a disturbance is in essence a process of the co-ordination of the behaviour of producers and consumers, the emphasis in Hayek's business cycle theory lies on the lack of co-ordination that is the result of disturbances that are caused or amplified by the monetary system. The series of publications dealing with business cycles do not analyze in any detail the co-ordination among the plans of economic agents, and with that the notion of interactive equilibrium as such.

What Hayek in fact does, is to assume, implicitly, the existence of what would now be called a representative individual. In his later work (for instance Hayek 1935c), Hayek mentions a type of economy to which his individual equilibrium concept may be applied as an idealization. It is what Wieser calls the "Naturalwirtschaft", or dictator economy, in which all the decisions are taken by a single central planner. He makes a systematic use of this idealization in The Pure Theory of Capital of 1941. In the course of that book this assumption is released.¹²

3. Expectations and interaction.

⁹ "Jene natürliche Abstufung der Preise in der Zeit, die den bei Naturaltausch entstehenden intertemporalen Tauschrelationen entsprechen würde ...wird...durch den Mechanismus jedes jemals verwirklichten oder denkbaren Geldsystems verhindert." (Hayek 1928: 58).

¹⁰ As Hayek puts it explicitly in his 1933: 17.

¹¹ Cp. Birner 1995b. The most important publications are Hayek 1931, 1933, 1939 and 1941.

¹² The failure to recognize this procedure has given rise to confusions. Two of these are criticized in Birner 1995c.

In 1928 Hayek had left the analysis of intertemporal general equilibrium theory in an unfinished state. He only discussed the equilibrium of the individual agent and the importance of expectations, and no more than indicate how the individual plans might be co-ordinated. Interaction among individuals takes place through exchange. That he did not go further into this problem at the time is because his main interest was the influence of the monetary system on the system of intertemporal prices. Yet, in "Price Expectations, Monetary Disturbances and Malinvestments" (Hayek 1935c), Hayek indicates that the extension of the notion of equilibrium of an individual plan to the interactive context is a separate problem that must be solved.

"While in [the case of economic activities of an isolated person or of a centrally directed communist system] we can legitimately speak of a necessary equilibrium between the decisions which a person will make at any moment, it is much less clear in what sense we can apply the same concept to the actions of a greater number of persons..." (Hayek 1935c: 139)

The solution involves the study of the formation and consequences of expectations.

"It is evident that the various expectations on which different individuals base their decisions at a particular moment either will or will not be mutually compatible; and that if these expectations are not compatible those of some people at least must be disappointed." (ibid.: 140)

Instead of working out the consequences of this in general terms, in the next paragraph Hayek returns to the analysis of business cycles. Equilibrium and co-ordination are briefly discussed within that framework. Equilibrium involves the intentions of consumers and investors being compatible (cp. pp. 143-4 and 145).

Hayek took up the theme of co-ordination explicitly in a different context in the same year: the debate on socialism. For the purpose of the debate, Hayek defined socialism as central planning by the government.¹³ His criticism of a socialist economy is that it is informationally inefficient in three ways. First, the millions of individuals who together make up an economy know their own specific circumstances in quite some detail. However, a centrally-planned economy lacks the means of collecting all these individual bits and pieces of information. Second, under a system of centralized decision making there are no incentives for individuals to discover new opportunities. And third, even if a central planning bureau had the means of collecting all relevant information, the computational demands would supersede the capacities of even the fastest computers.

In 1935a Hayek clearly distinguishes between the analysis of the economic problem of the individual, allocating given means to given ends, with given prices, on the one hand, and the economic problem of a society as a whole, where the prices are no longer given.¹⁴ He refers to Wieser's "Naturalwirtschaft", an economy with a single set of given ends, as an idealization.¹⁵ Although he does not use the term, he discusses equilibrium implicitly.

"Decisions of whether and how much to produce of a thing are economic decisions in this sense [cp. note 13]. But the making of such a decision by a single individual is only part of the solution

¹³ For a detailed discussion of the contributions by Hayek, and of those by Mises, to the debate on socialism, cp. Keizer 1994.

¹⁴ Notice that Hayek uses Robbins' definition "the distribution of available resources between different uses" (Hayek 1949: 121). Cp. also: "The economic problem arises, therefore, as soon as different purposes compete for the available resources." (p. 123).

¹⁵ As I observed above, in PTC Hayek was to use Wieser's dictator economy as a point of departure for his analysis. The assumption of one decision maker is later released. However, throughout the book the price system is assumed to co-ordinate the plans of different individuals. The analysis of its functioning was apparently left over for the second volume, on dynamics, which was planned but never written. All this confirms the idea that while Hayek was occupied with his business cycle theory, the problem of the process of co-ordination was pushed into the background.

of the economic problem involved. The person making such a decision makes it on the basis of given prices. The fact that by this decision he influences these prices to a certain, probably very small, extent will not influence his choice. The other part of the problem is solved by the functioning of the price system." (Hayek 1935a: 123-4)

In the last two sentences Hayek clearly distinguishes between the economic problem for an isolated individual and for the system as a whole. However, even here he does not discuss this further. He simply presents the price system (again) as a solution to this problem. The price system is the co-ordinating device. Competition, the analysis of which is the "permanent contribution" of classical economics (p. 127), is mentioned but not elaborated. The themes of his later publications, knowledge and its distribution, are not even mentioned. This is only the case in his second article on socialism. Taylor, Roper, and Dickinson had argued that "on the assumption of complete knowledge of all the relevant data" (Hayek 1935b: 152) general equilibrium theory may be used to determine centrally the production of commodities. Hayek observes that this is not impossible in the sense of being logically contradictory (Hayek 1935b: 153). "But what is practically relevant here is not the formal structure of this system [such as Barone's system of equations] but the nature and amount of concrete information required if a numerical solution is to be attempted..." He goes on to discuss to what extent this would come close to the solution a competitive system yields. One objection to Taylor c.s. is that the central planner would have to know all the details of all production processes. He would also have to know all new technologies. However, these often exist only as tacit knowledge or skills (Hayek does not use these terms) which cannot be communicated explicitly. Hayek discusses competition quite extensively, and returns to the subject in his third socialism article (Hayek 1940).¹⁶

4. Information, distributed knowledge, and co-ordination.

Thus, it was only as a consequence of his discussion of the distribution of knowledge and its co-ordination in the socialism debate that Hayek explicitly took up the analysis of interactive equilibrium, the problem that had been left over from his 1928 article. The first occasion is "Economics and Knowledge, read in 1936 and published in 1937. This is followed by another article dealing with the co-ordination of individual plans by the price system (Hayek 1945) and a series of articles about competition, beginning with Hayek 1946. I will discuss the first of these, "Economics and Knowledge" in quite some detail.

In 1928 Hayek had defined equilibrium for the individual agent. Equilibrium of the system as a whole is not presented clearly as a separate problem. Hayek assumes that the price system somehow co-ordinates the individual plans. He does not analyze how this takes place. He only mentions that what is involved is the fact that the expectations of some individuals will be disappointed. Hayek 1937 repeats the idea that was expressed in Hayek 1935c, viz. that the concept of equilibrium of the individual planner cannot be applied to the economy as a whole.

"I have long felt that the concept of equilibrium itself and the methods which we employ in pure analysis have a clear meaning only when confined to the analysis of the action of a single person and that we are really passing into a different sphere and silently introducing a new element of altogether different character when we apply it to the explanation of the interactions of a number of different individuals." (1937: 35)

¹⁶ Cp. for instance p. 196: "the method which under given conditions is the cheapest is a thing which has to be discovered, and to be discovered anew, sometimes almost from day to day, by the entrepreneur..." and "at his own risk".

The concept of "datum", of what is given, constitutes the main problem: "in the transition from the analysis of the action of an individual to the analysis of the situation in a society the concept [of datum] has undergone an insidious change of meaning." The process of co-ordination is now promoted to first position: "why the data in the subjective sense of the term should ever come to correspond to the objective data is one of the main problems we have to answer." (p. 39). This problem has various dimensions. First, the nature of the data. Hayek pays much attention to this, first in his 1937. "The Facts of the Social Sciences" of 1942 is entirely devoted to the problem. Furthermore, there is the question as to whom the data are given. This is discussed in Hayek 1937, 1942, and 1945.

In Hayek 1937, the distinction between individual equilibrium and equilibrium of the system as a whole (or interaction equilibrium) is linked in a very ingenious way to the distinction between the a-priori part of economic theory and the empirical part. This marks a departure from the ideas of Mises. Cp. Hayek on Hayek: 72:

"What I see only now clearly is the problem of my relation to Mises, which began with my 1937 article on the economics of knowledge, which was an attempt to persuade Mises himself that when he asserted that the market theory was a priori, he was wrong; that what was a priori was only the logic of individual action, but the moment that you passed from this to the interaction of many people, you entered into the empirical field."

The link enables Hayek to pose the problem of the co-ordination process in terms of the question about the empirical content of economic theory. Hayek's solution lies in his description of the logical structure of economic theories. They consist of two parts: the pure logic of choice, and a set of hypotheses about how subjects acquire information. The pure logic of choice consists of the set of "tautologies, of which formal equilibrium analysis in economics essentially consists (...)". (Hayek 1937, 33). By definition, these tautologies lack empirical content. But they

"can be turned into propositions which tell us anything about causation in the real world only in so far as we are able to fill those formal propositions with definite statements about how knowledge is acquired and communicated. In short, I shall contend that the empirical element in economic theory - the only part which is concerned not merely with implications but with causes and effects and which leads therefore to conclusions which, at any rate in principle, are capable of verification consists of propositions about the acquisition of knowledge." (Hayek 1937: 33; emphases added)

By theoretical economics Hayek means general equilibrium theory. That theory is tautologous. That economics is nevertheless an empirical science is because it presupposes that in reality economies tend towards equilibrium: "the only justification for [the admittedly fictitious state of equilibrium] is the supposed existence of a tendency toward equilibrium. It is only by this assertion that such a tendency exists that economics ceases to be an exercise in pure logic and becomes an empirical science (...)" (p. 44) And

"the real content of the assertion that a tendency toward equilibrium exists (...) [is] that, under certain conditions, the knowledge and intentions of the different members of society are supposed to come more and more into agreement (...). In this form the assertion of the existence of a tendency toward equilibrium is clearly an empirical proposition (...). The only trouble is that we are still pretty much in the dark about the conditions under which this tendency is supposed to exist and the nature of the process by which individual knowledge is changed." (p. 45 emphasis added)

The usual analysis assumes knowledge to be perfect. However, this is no solution, as equilibrium is defined as a state of perfect knowledge. This is enough to keep the learning

behaviour of agents out of the core of general equilibrium analysis. But this turns the situation on its head.

"The significant point here is that it is these apparently subsidiary hypotheses or assumptions that people do learn from experience, and about how they acquire knowledge, which constitute the empirical content of our propositions about what happens in the real world. They usually appear disguised and incomplete as a description of the type of market to which our proposition refers; but this is only one, though perhaps the most important, aspect of the more general problem of how knowledge is acquired and communicated. The important point of which economists frequently do not seem to be aware is that the nature of these hypotheses is in many respects rather different from the more general assumptions from which the Pure Logic of Choice starts." (p. 46)

The argument clearly shows that Hayek does not part with equilibrium analysis. Only he realizes much better than in 1928 that the social structure of which the agents are part is of vital importance to the co-ordination of individual plans.¹⁷

5. Hayek on markets and competition.

So far, I have given some of Hayek's general arguments about markets and competition. I will now summarize, in a rational reconstruction, what Hayek says in detail about the functioning of markets and competition in his articles of 1937, 1945 and 1946.

Economic problems arise as soon as unforeseen (1937: 48, 1946: 101) changes occur. They falsify the expectations on which agents had based their plans. Thus, they are forced to adapt their plans (1945: 82). The mechanism that transmits the signals of these changes is the price system. It translates all changes within the system into a one-dimensional quantity: prices. Price signals together with individual preferences provide sufficient information for the agents to adapt themselves to the changed circumstances. Even though they are one-dimensional carriers of information, prices transfer knowledge very efficiently (1945: 86). The signals are transferred within the system because the fields of vision of individuals overlap (1937: 53). An agent's plan determines his market behaviour: what and how much he demands and supplies. Changes within the system that force him to adopt his plan *ipso facto* influence his market behaviour. In order to effectuate changes in his plan, agents have to participate in the market process (1937: 53). In doing so they generate signals for other market parties, who in their turn adapt their plan and their behaviour. This makes that the signals are transmitted.

The fact that an individual's behaviour generates signals also means that he uses the knowledge which he has gathered because he is acquainted with his own particular, local situation. As much of this knowledge is implicit, it cannot be fully formulated in explicit terms. People dispose over much more knowledge than explicit knowledge (1945: 83). The automatism with which the system of prices transmits implicit knowledge, too, is a great advantage. The existence of a "system of telecommunications" (1945: 87) of prices is a condition for the tendency to equilibrium that we can observe. One of the other conditions is the

¹⁷ The break that authors such as Bruce Caldwell (1985) and Terence Hutchinson (1981: 214ff.) choose to see in Hayek's development, and which they locate in his 1937 article, does not exist. Hayek himself denies that there is such a break, as he keeps repeating the importance of equilibrium analysis (cp. for instance the second chapter of PTC, and particularly p. 21). Laidler's assessment is even wider of the mark. He asserts that Hayek, "beginning in 1937, he began to propagate a very different view of market processes to the Walrasian equilibrium approach which underlay his business cycle theory..." (Laidler 1994: 20). If Laidler means by "Walrasian" Hayek's generalized, intertemporal framework, then he is wrong that Hayek began to propagate an entirely different view on markets. And if by "Walrasian" he means static general equilibrium theory, he is wrong in thinking that this theory underlies Hayek's theory of disequilibrium growth.

free functioning of competition.

The process of the division of labour has gone hand in hand with the division of knowledge. The world has become too complex to be understood in all its aspects by one mind. Without possibilities to coordinate the knowledge that is locally available in a distributed form, the division of labour would soon have come to a standstill. However, with the progress of specialization or division of labour the price mechanism and competition co-evolved. Through competition the relevant knowledge which agents (and particularly entrepreneurs) have of their own specific situation, knowledge about costs, about the preferences of consumers and about the existence of new products or about the possibilities of developing them is discovered (1946: 96). Entrepreneurs translate their discoveries in market behaviour, which generates price signals that are transmitted by the price system. In this way human behaviour adapts itself optimally to the changed objective circumstances (1946: 102) (which also comprise the behaviour of others; 1937: 38). The more complex this set of objective data is, the more important is competition (1946: 103). Competition is a process which mobilizes the forces that equilibrate the economic system.

Competition is essentially a process of the formation of opinion: by spreading information, it creates that unity and coherence of the economic system which we presuppose when we think of it as one market. It creates the views people have about what is best and cheapest, and it is because of it that people know at least as much about the possibilities and opportunities as they in fact do. It is thus a process which involves a continuous change in the data and whose significance must therefore be completely missed by any theory which treats these data as constant. (1946: 106)

Theories that assume a situation of "perfect competition" (which usually refers to homogeneous goods, atomistic markets with free entry and exit and perfect information) in fact deny the existence of competition. Competition only works where all these circumstances do not obtain. The assumption of perfect competition has disastrous consequences for the empirical content of each and every theory that predicts a tendency to or the existence of equilibrium. It is reduced to a tautology. That is because equilibrium is defined as the situation in which there is perfect information (1937: 42). Theories that make this mistake confuse both parts of economic theory: the equilibrium analysis of the pure logic of choice and the explanation of the process of coordination (1937: 46).

The economic problem of a society consists of the continuous discovery of new ways of satisfying the wishes of people (1946:101). The discovery process can only function within an institutional framework that is such that "the unknown persons who have knowledge specially suited to a particular task are most likely to be attracted to that task." (1946: 95).

6. Core features of Hayek's market model.

Let me now pause to highlight some of the central elements of Hayek's ideas on markets and competition.

1. The importance of an agent's position for the acquisition of the knowledge necessary for system equilibrium to prevail. Cp. p. 53: "the relevant knowledge which he [the individual] must possess in order that equilibrium may prevail is the knowledge which he is bound to acquire in view of the position [added] in which he originally is, and the plans which he then makes."

2. The element of what we may call local learning or position-constrained learning.¹⁸ The passage just quoted continues:

¹⁸ This is a central element of Gilles' model, which will be discussed below.

"It is certainly not all the knowledge which, if he acquired it by accident, would be useful to him and lead to a change in his plan. We may therefore very well have a position of equilibrium only because some people have no chance of learning about facts which, if they knew them, would induce them to alter their plans. Or, in other words, it is only relative to the knowledge which a person is bound to acquire in the course of the attempt to carry out his original plan that an equilibrium is likely to be reached."

3. This at the same time introduces the element of path-dependency.

4. The elements of connectivity is introduced in various ways. Hayek discusses the amount of knowledge which would be needed in a decentralized system in order that it may reach the same equilibrium that an omniscient dictator would impose as "a sort of optimum position" (Hayek does not explain what he means by optimum, but the text makes it clear that it is a situation in which no relevant knowledge is left unused so that no individual has a motive to change his plan; an indirect way to express a Pareto optimum.) Cp. Hayek 1937: 53: "One condition [for the decentralized-system equilibrium to coincide with that of the centralized dictator-economy] would probably be that each of the alternative uses of any sort of resources is known to the owner of some such resources actually used for another purpose and that in this way all the different uses of these resources are connected [sic!], either directly or indirectly." The note to this sentence elaborates on the theme of what in modern network theory is called the connectedness of networks:

"That it is not necessary, as one might think, that every possible use of any kind of resources should be known to at least one among the owners of each group of such resources which are used for one particular purpose is due to the fact that the alternatives known to the owners of the resources in particular uses are reflected in the prices of these resources. In this way it may be a sufficient distribution of knowledge of the alternative uses, m, n, o, ...y, z, of a commodity, if A, who uses the quantity of these resources in his possession for m, knows of n, and B, who uses his for n, knows of m, while C, who uses his for o, knows of n, etc., until we get to L, who uses his for z, but knows only of y.¹⁹

5. Consider Hayek's criticism of contemporary formal equilibrium analysis, where the problem of the distribution of knowledge is defined away. Individuals make plans based on their own preferences and the "data" which are available in the form of signals generated by other individuals, and they do so through time. Hayek's criticism of traditional equilibrium theory is that it is circular: "Correct foresight is ... not, as it has sometimes been understood, a precondition which must exist in order that equilibrium may be arrived at. It is rather the defining characteristic of a state of equilibrium."²⁰ This is tantamount to the criticism that such theories tacitly assume fully connected networks. Notice also that Hayek's emphasis on the importance of the acquisition of knowledge is very similar to the models suggested by Kirman and by Gilles, which will be discussed below.

6. The theme of connectivity is very strongly represented in Hayek 1945. Cp. p. 86: "The whole acts as one market, not because any of its members survey the whole field, but because their limited individual fields of vision sufficiently overlap so that through many intermediaries the relevant information is communicated to all." However, Hayek does not understand that this defines a research problem rather than a solution (in the form of the price system). To mention one problem, the speed with which the information is transferred obviously matters. If the local information spreads slowly, there may not be a tendency towards equilibrium. But the study of

¹⁹ Cp. Desai 1994 for a discussion of the revolutionary character of Hayek's posing the problem of the division of knowledge.

²⁰ Cp. also Hayek 1937: 46: "The statement that, if people know everything, they are in equilibrium is true simply because that is how we define equilibrium."

this problem had to wait until the 1970s, when sociologists started examining the effects of the characteristics of networks for the speed and accuracy with which information is transferred.

7. The element of acquiring knowledge and experience through experience and the building up of personal contacts. Cp. Hayek 1945: 80, where Hayek speaks of "a body of very important but unorganized knowledge" which is not scientific. "We need to remember only how much we have to learn in any occupation after we have completed our theoretical training, how big a part of our working life we spend learning particular jobs, and how valuable an asset in all walks of life is knowledge of people, of local conditions, and of special circumstances."

All these features are characteristics of what nowadays are called network models. Indeed, I will argue that Hayek's theory of markets and competition is a network theory. But before I do that, I have to explain what network theory is about.

7. Networks.

A network is a structure which consists of a set of units or nodes and the relationships or links among the units.²¹ The relationships may be distinguished according to their form (for instance, symmetrical, asymmetrical, transitive, intransitive, uniplex, multiplex) and their content (such as transaction, communication, sentiments, power, kinship).

Structural features of the whole may be summarized in aggregate form parameters. Examples are size (the number of units in the network), density (the ratio of the actual number of relations to the possible total number of relations among units), interconnectedness (the average number of relations that each unit has with others) and cluster structure (the subdivision of the network into sub-networks which are internally more connected than externally).

If the units are neurons and the connections nerves, the resulting model is a neural network model. If the units are human individuals and the connections are friendship bonds, we obtain a friendship network, as in the work of Zeggelink. If the units are humans and the relationships are information channels, we have a communication network, as for instance in the work of Granovetter. With humans as units and exchange relationships we get an exchange network. Areas where network models are used are neurology, artificial intelligence, and sociology. In economics, network models are very rare. I will mention a few examples below.

One of the network models that is perhaps best known to economists is Granovetter's strength-of-weak-ties model. It has been developed originally to model job-seeking behaviour, and in sociology it has given rise to a host of social network models. The original model served to explain how people learn about new job opportunities. Information about job openings travels through the structure of interpersonal relationships. The transmission of information involves the ability of the social structure to transmit information efficiently and without distortion. The crux of the strength-of-weak-ties argument is that differences in communication behaviour are caused by differences in social networks. In their turn, the characteristics of networks are defined in terms of the attitudes of the individuals of which the network is made up. Individuals have various types of "ties" with one another. The nature of the ties determines both the nature and the frequency of the interactions. Ties are distinguished in terms of the differences between individuals as similar or homophilous and dissimilar or heterophilous. It is assumed that homophily is correlated positively with strong ties and heterophily with weak ties. Another dimension of interactions or relationships is their multiplicity, i.e. the number of different social roles in which individuals interact. Multiplicity is positively correlated to strength. So we arrive at the hypothesis that the greater the number of social roles in which agents interact, the stronger their ties. Through a number of intermediate steps, the model formulates the following

²¹ I follow para. 1.1.1.1 of Zeggelink 1993.

predictions. The more a society consists of networks that are characterized by weak ties, the faster will more comprehensive and less distorted information be distributed over more agents who are more tolerant. Conversely, the more a society is characterized by closed or strong-tied networks, the more slowly will less comprehensive and more distorted information be distributed over fewer agents and agents who are less tolerant.

Granovetter is not the only sociological network theorist to study economic phenomena. Harrison White uses a network model to study the emergence and stability of different types of market relationships (cp. for instance White 1988, 1993). White studies a particular type of market, the market for products that are purchased by industry (he calls them production markets). These markets are established and kept alive only if the structure of relationships among suppliers and purchasers is such that their perception of the situation is sufficiently congruent. Otherwise, a market will disappear. Thus, these markets only exist by virtue of the mutual compatibility of the perceptions of the market parties. Because acts of individual perceptions are involved, why White speaks about the stability of these markets in terms of their being reproduced. In the light of Hayek's work we may observe that what White in fact does (though he is not influenced by Hayek as a matter of history) is to elaborate the Hayekian subjectivist idea that markets are social constructs in the sense that they only exist if people believe themselves to be in a market-like environment (cp. for instance Hayek 1943).

Another sociological network theorist who addresses economic phenomena is Ronald Burt. His latest book, Structural Holes; The Social Structure of Competition, is about a particular type of entrepreneurship. Burt models the economy as a network of agents. There may be connections that are possible yet have not been realized. Burt calls these 'structural holes'. In this analysis,

"competition is a matter of relation, not player attributes. The structural hole argument escapes the debilitating social science practice of using player attributes for explanation. The relations that intersect to create structural holes give a player entrepreneurial opportunities to get high rates of return. The player in whom the relations intersect - black, white, female, male, old, young, rich, poor - is irrelevant to the explanation. Competition is not about being a player with certain physical attributes; it is about securing productive relationships. Physical attributes are a correlate, not a cause, of competitive success. Holes can have different effect for people with different attributes or for organizations of different kinds, but these differences in effect occur because the attributes and organization forms are correlated with different positions in social structure. The manner in which a structural hole is an entrepreneurial opportunity for information benefits and control benefits is the bedrock explanation that carries across player attributes, populations, and time." (Burt, 1992: 4)

Burt's entrepreneurs discover unrealized network connections, and once they have discovered these they attempt to establish themselves as gatekeepers in order to preserve the profit which they derive from their position in the network. In turn, the bridging of a hole will call forth attempts on the part of other entrepreneurs to create parallel bridges, which will increase the profits of the newcomers but erode those of the initial hole-fillers.

It is of some historical interest that Burt offers a more formal analysis of a type of entrepreneurship we find in the work of Ludwig von Mises (Burt does not refer to Mises). Mises offers a "structural" theory of discovery in his discussion of the role of the entrepreneur in his contribution to the debate on socialism. He stresses the importance of positions in a social structure:

"Like Plato's philosophers, the directors so appointed [i.e. in public enterprises] may well be the wisest and best of their kind, but they cannot be merchants in their posts as leaders of a socialist society, even if they should have been previously." (Mises 1920: 121).

This is because

"[a] merchant's qualities are not the property of a person depending on inborn aptitude, nor are they acquired by studies in a commercial school or by working in a commercial house.... The entrepreneur's commercial attitude arises from his position in the economic process and is lost with its disappearance." (ibid.).

Sociological network theory is a thriving subject. It seems as if no economist has recognized the potential that some sociological network models have for solving problems of economic analysis. Yet some economists have developed network models of their own. One is Alan Kirman. He observes (Kirman 1983) that the structure which a Walrasian economy presupposes is star-shaped. All transactions are modelled as being conducted via a central auctioneer. This is the structure of a centrally-planned economy. Applying it to a market economy is paradoxical, because the latter has the structure of a network of multiple relations among individuals. But "once we break away from the "star-like" structures of a classical economy with central auctioneer, who trades with whom, and who passes information to whom becomes very significant." (Kirman 1983: 107). Kirman offers an extension or generalization of traditional neoclassical economics which incorporates dynamics, information, communication and co-ordination (see also Kirman 1985, 1991).

Another economic network theorist is Gilles (see Gilles 1990). He extends traditional general equilibrium theory by embedding the economy in a hierarchical social structure, of which he gives a formal analysis. Traders are part of a network in which communication is passed on and exchange takes place after prices have been established in a recontracting process. What sociologists would call a network roughly coincides with what Gilles calls a pre-network. A pre-network is (roughly) a coalition with certain characteristics that has the properties of reachability and connectivity.

"The reachability condition as defined above is reflecting the notion, that an organization structure in a relationally structured economy has to be reached directly by every agent in the population."
"Connectivity is a formalisation of the natural condition that a communication device has to be able to send a message from one agent to any other agent in the economy. In a trade economy, a pre-network can be regarded as a trade-organization structure consisting of shipping and distribution institutions such as shops, transportation firms, and mining corporations. Reachability now states that any agent in the population is able to go to a shop, while the connectivity condition demands that any agent in the population can potentially be provided by any commodity in the economy." (p. 112; emphasis deleted)

There is no space to discuss Gilles' model in any detail, so I will just indicate another parallel with sociological network theory. Gilles distinguishes between complete communication and full communication (p. 74). In the case of full communication there is (the possibility of) indirect communication, while in the case of complete communication every agent potentially has a direct relationship with every other agent. This is what sociologists would call a fully-connected social network. Thus, in a complete communication model there is no asymmetry in the social position of agents.²²

Let me return to the notion of a network. Gilles defines a network as what might be called a non-redundant pre-network. Cp. p. 114, where a network is defined as a minimal pre-network. "This minimality condition requires that there are no superfluous agents in the pre-network, who can be disposed of without distorting the reachability and connectivity properties of that pre-network." This leads to the description of a situation which we also find in Burt:

²² This amounts to a strong homogeneity postulate (one that is criticized in Hayek 1937; see also Garretsen 1994 and Van Zijp & Visser 1994).

"It is clear that the notion of a network as introduced in the previous chapter is exactly describing a group of traders who have positional advantages over the other traders in the economy. The existence of such a trade organization is thus a natural consequence of the relational imperfections as described by the relational structure of the population of the economy. A trade organization describes the domination of certain traders over others, resulting from their positional advantages, as well as the asymmetric positions of traders on the market." (p. 144, emphasis deleted)

8. Hayek's theory of markets and competition as a network theory.

We can now see that the central features of Hayek's publications on markets and competition are basic elements of network theories of the dynamic variety. Hayek's model in fact describes markets as social structures. It builds upon the notions of connectivity,²³ local or position-constrained learning,²⁴ and path-dependency in the explanation of the division of knowledge and its co-ordination. Hayek's model of markets and competition is a dynamic network model.

In addition to the specific network elements mentioned above, there are some generic similarities between Hayek's work and modern network theory. Thus, the system as a whole is capable of dealing with more complex problems than the (sum of) the separate elements. Also, learning is a property of the system. This is the crux of Hayek's cognitive psychology, and it is the argument Hayek later makes about social systems in "Individualism: True and False" of 1945. One might say that it would be a logical consequence of Hayek's ideas to apply neural network theory to social systems (which is being done; cp. for instance Stokman & Zeggelink 1995).

The long passage quoted above, in section 4 of the paragraph "Core features", (which is a footnote; but see also the text to which this footnote belongs) may be considered as a less formal expression of one of the ideas that one finds in Gilles of the distinction between direct and indirect communication.

Finally, "network(ing)" in the empirical (and popular) sense of the building and maintaining of personal contacts²⁵ is also represented in the sequence of Hayek's articles that I discuss here. Students of the industrial districts in Northern Italy and of organizations will find many of Hayek's remarks very familiar.

9. Theory of mind and theory of society.

The origin of Hayek's description of markets and competition in network-like terms lies in his very earliest intellectual product. In 1920, Hayek, as a 21-year old student, wrote a manuscript on cognitive psychology. The manuscript can be found in the Hayek archives at the Hoover Institution at Stanford. It is 41 double-spaced pages long and its title is Beiträge zur Theorie der Entwicklung des Bewusstseins. A note in Hayek's hand informs us that this manuscript is a typewritten copy of the original, made probably in the late 1940s. A comparison of the type-written transcript of the original manuscript with the published text shows that the two are very similar. Therefore it makes sense to discuss the published version if we want to

²³ Desai 1994 uses the words "connectedness" (p. 41) and "network" to characterize Hayek's position without referring to systematic attempts in contemporary economics and sociology to elaborate these notions.

²⁴ For the argument that the information an individual receives depends on his position in the structure, cp. Granovetter's observation that "[s]tructural embeddedness also affects the behavior of individuals by its impact on what information is available when decisions are made." (Granovetter 1992: 36).

²⁵ Cp. for instance Beije & Groenewegen 1992.

find out whether Hayek's ideas about markets and competition were influenced by the psychology of his early days. The outline of Hayek's cognitive psychology will be given in Appendix A. The question whether Hayek's psychology influenced his thinking about markets and competition raises a historical problem that will be dealt with in Appendix B. For the moment it is sufficient to know that Hayek cognitive psychology is a network theory. His book was even an important source of inspiration for the development of neural network theory, the other being Donald Hebb's The Organization of Behaviour of 1949. Both were starting points for the development of models of parallel distributed processes (PDP) or neural networks (NN). George observes: "The idea that the human senses worked on a classification principle had previously been suggested by Hayek (1952), and Uttley was able to build a simple classification system in hardware." (George 1961: 112). On p. 319 the same author remarks: "It was Hayek (1952) who first suggested that the method of human perception was dependent upon a classification system. This suggestion was followed up by Uttley (1954, 1955) ..." And Rosenblatt 1958 mentions Hayek's book, together with Hebb's as the most suggestive for later work on perceptrons.

10. Coordination of distributed knowledge as a network phenomenon.

In the above, I have argued that Hayek's theory of the functioning of markets and competition may be reconstructed in terms of a network model. However, the publications specifically devoted to markets and competition hardly contain any idea about how markets emerge. For this one has to look at Hayek's later work, which is concerned with the evolution of social institutions in general. Hayek's renewed involvement with cognitive psychology, when he prepared the text of SO after the war, influenced his social theory.

Interestingly enough, Hayek's theory of social institutions, too, has (neural) network-like characteristics. I mention a few examples.

The conception of the human mind as a self-organizing system can be considered as ancestral to Hayek's idea that most social institutions are spontaneous, self-regulating systems.

A spontaneous social order is capable of performing more complex tasks (or more tasks) than an organization that has been consciously created for the purpose. This has a close parallel to the theory of the mind of SO, a parallel that is even closer in Hayek's assertion that social institutions cannot be understood by man, the reason being that, by assumption, these institutions are capable of handling more complexity than the individual human mind.

The argument that the genetic and the functional aspects of spontaneous orders cannot be separated, which we find in "Arten der Ordnung", (Freiburger Studien, 1967: 36) seems to be taken over directly from SO. According to Hayek, the way in which both the human mind and social institutions function can only be explained in terms of the evolution of their structure.

The evolution and "natural" selection of institutions finds its parallel in the description of the working of the mind, which modifies classifications that are found to be inconsistent with new sensory stimuli.

The argument in SO about the conservation of past knowledge foreshadows Hayek's argument that spontaneously evolved institutions contain the "wisdom of ages".²⁶

"Sense experience (...) presupposes the existence of a sort of accumulated 'knowledge', of an

²⁶ The 1920 ms. states this mental conservation principle in even stronger terms: "Die Vorstellung dass dies darauf beruht, dass auch scheinbar verschwundene Kenntnisse weiterwirken, dass also nichts, gar nichts, dass wir einmal erfahren haben, ganz verloren geht, ist überaus ermutigend." (p. 29) (The idea that this is based on the fact that even seemingly lost knowledge keeps being influential, so that nothing, nothing at all of what we have once experienced is completely lost, is very encouraging.) For copyright reasons, please do not quote this passage.

acquired order of the sensory impulses based on their past co-occurrence; and this knowledge, although based on (pre-sensory) experience, can never be contradicted by sense experiences and will determine the forms of such experiences which are possible." (SO 8.8)

In the mind, the function of an element (a neuron) is determined by its position in the whole of relations between elements. This finds its parallel with the argument in ITF, on p. 17, (and later in LLL) that "the relative importance to him [individual man] of the different results he can achieve must correspond to the relative importance to others of the more remote and to him unknown consequences of his action" is one of the conditions (the other being a well-delimited sphere of responsibilities) for a maximum contribution of an individual to the whole.

As a last item, I mention the argument in Hayek 1945a about learning and rationality as properties not of individuals but of social systems.

From Hayek's social philosophy we may derive the suggestion that there is another way in which markets and networks may be linked. The argument may be called historical, or, following Menger, genetic. I have already briefly discussed Granovetter's early network theory, which is static in the sense that it does not deal with the evolution of networks. In his later work, Granovetter hints at an interesting link between his weak-ties model and the division of labour in a dynamic context: "In the evolution of social systems, perhaps the most important generator of weak ties is the division of labor, since increasing specialization and interdependence result in a variety of specialized role relationships, in which one knows only a small segment of the other's personality." (Granovetter 1982: 107). One of the insights of Adam Smith is that the emergence of markets and the process of the division of labour are closely linked. Thus, the process of the emergence and further spreading of markets would seem to be the same process in which an increasingly complex network of weak ties develops. If we add to this set of hypotheses Hayek's thesis that it is not so much the division of labour that underlies the development of the modern market society, but rather the division of knowledge,²⁷ we arrive at the hypothesis that the increasing division of labour goes hand in hand with the growth of a network consisting of weak ties. However, this hypothesis goes far beyond what we can find about markets in the work of Hayek. Hayek admits that with his 1937 article he has come to the limits of his insights:

"I am afraid that I am now getting to a stage where it becomes exceedingly difficult to say exactly what are the assumptions on the basis of which we assert that there will be a tendency toward equilibrium, and we should and to claim that our analysis has an application to the real world. I cannot pretend that I have as yet got much further on this point. Consequently, all I can do is to ask a number of questions ..." (48)

Hayek himself failed to develop his ideas about the functioning of markets much further. His own "The Use of Knowledge in Society" of 1945 even marks a step backward from the direction indicated in his "Economics and Knowledge" of 1937. In the later article the problem of the coordination of distributed knowledge is seen as being solved by the price system. Desai uses Hayek's own example of the tin market to effectively criticize this "solution". Desai points out fact that the tin market in the 1940s relied on a highly developed network of informants and information that encompassed far more than just prices. Hayek 1945 is very disappointing as compared to Hayek 1937 because the later article leaves out all the non-price network and connectedness aspects (cp. Desai 1994). I share Desai's disappointment. But on the other hand, I hope to have shown that the article on economics and knowledge and the ones about competition contain a sufficient number of promising hints that we may speak of a research

²⁷ In fact, this is a generalization of Smith's argument, which perhaps explains the positive correlation between specialization and increased productivity better than the division of labour.

programme. One, it is true, that is still awaiting elaboration, although some work has already been done. I hope to show this in the next paragraph.

Two final remarks about network theory. First, the link between social and neural networks is not spurious. In recent work neural network models are used to describe the self-organization of social processes (cp. Stokman & Zeggelink 1995). Second, network theory has the potential to serve as a general framework for markets, hierarchies, and intermediate forms of social organization (cp. Williamson 1993).

11. Early progress in economics on markets as networks.

There is no evidence that any of the modern network theories, either in sociology or in economics, have been influenced by Hayek's work. However, there is one author who might be considered an exception. I am referring to G.B. Richardson. His work shows a strong influence of Hayek, and particularly Hayek's 1937 article. In his Information and Investment of 1960 Richardson elaborates Hayek's criticism of mainstream general equilibrium theory and of the assumption of perfect competition.²⁸ The resulting theory has clear network features.²⁹

Information and Investment reads like a systematic elaboration of the programmatic statements of Hayek 1937. It takes its point of departure in Hayek's emphasis on the importance of the question "how much knowledge and what sort of knowledge the different individuals must possess in order that we may be able to speak of an equilibrium." (Hayek 1937: 50). The theme that an individual's attainable information is dependent on his position in a network is central to Richardson's book:

"The conventional ways in which we introduce expectations into economic theory seem to me to have this crucial deficiency; they ignore the fact that expectations are based on information, and that the availability to entrepreneurs of the required information is, in part, dependent on the nature of the market structure or system of relationships within which they operate." (Preface)

One important element in the book is the idea that maintaining relationships between suppliers and purchasers can be advantageous even if this is temporarily not profitable. Another is that entrepreneurs, when planning an investment, take into account relations of both competition and complementarity.³⁰ This provides a richer structure than can be found in standard neoclassical models of investment and market relationships. This is reaffirmed in Richardson 1972: "The dichotomy between firm and market, between directed and spontaneous co-ordination, is misleading; it ignores the institutional fact of inter-firm co-operation and assumes away the distinct method of co-ordination that this can provide." (p. 895). Richardson's model has an interaction structure that is much richer than Hayek 1945. Thus, he describes entrepreneurial behaviour as in part directed at an active reduction of uncertainty. Interaction among enterprises does not take place only through the price system. With respect to competitive investments entrepreneurs may enter into collusion. With respect to complementary investments they may follow different strategies, such as speculating on the existence of overcapacities in the industry producing the complementary products (in the case of small

²⁸ In correspondence, Richardson says that his analysis of how different market structure influences the availability of information to the firm owes nothing to Hayek. Yet it cannot be denied that Richardson's point of departure is a criticism of perfect competition models that is very similar to Hayek's, and that his emphasis on the importance of information is very Hayekian. In an article of 1953 Hayek's influence on Richardson is quite obvious.

²⁹ Richardson later even uses the word "network" (for instance Richardson 1972: 883). In a way, Richardson's work provides a sort of "indirect proof" of my thesis that Hayek's economics contains network elements.

³⁰ For who doubts Hayek's influence on Richardson, let me observe that complementarity is central to one of Hayek's earliest publications, Hayek 1926.

investments), or vertically integrating an enterprise producing complementary parts. These are the sort of strategies one finds described in the work of network sociologists such as Burt and White.

The work of Richardson would deserve a separate discussion, for which there is no space here. Let me close this paragraph by saying that I think it fair to conclude that on the level of ideas Richardson's work bridges some of the gap that exists between Hayek 1937 on the one hand, and later work in sociological network theory and the network models in economics on the other hand. It is one of the curiosities of intellectual history that as a matter of fact there has been no such influence.

12. Conclusion.

Mainstream economics has a firm allegiance to general equilibrium theory. Network models might be seen as a threat to its position. However, the work by Hayek, Kirman and Gilles shows that this fear would be unjustified. There is a close parallel between Gilles' socially structured economies and Hayek's argument about the structure that economic theory needs to have in order for it to have empirical content (Gilles nowhere refers to Hayek). Both keep the general equilibrium framework (though Gilles does not discuss intertemporal equilibrium), and both add to it a structure of communication networks. Moreover, both authors argue that this social structure has to be examined for the conditions that lead to equilibrium (or under which equilibrium exists). Extending the general equilibrium model into a model describing a more complex social structure is tantamount to the procedure through which science usually grows.³¹

Some of Hayek's ideas, such as self-organization as a characteristic of social institutions, and the importance of information for coordination, are now being elaborated in modern network models.³² Others still await further research. We should not limit ourselves to studying Hayek's economics. In his later work, Hayek studied the evolution of social institutions. He did not analyze in much detail the emergence and evolution of one of the most important social institutions of modern society, markets. There is nothing, however, that keeps us from applying an evolutionary approach to markets. One of the things that waits to be examined is how market relationships may spontaneously emerge out of the interaction between individuals, taking into account how they perceive their environment. As a sequel of the theoretical and empirical work in sociological and economic network theory, simulations and laboratory experiments offer prospects of making further progress in understanding markets.

Appendix A: The Sensory Order.

According to Hayek's cognitive psychology, the objects in the world belong to two "orders": the physical order, where events are similar or different according to whether they produce similar or different other external events; and the sensory order, in which events are classified according to their sensory properties. In contrast to Ernst Mach, Hayek holds that there is no simple one-to-one correspondence between the elements of the two orders. Indeed, this criticism of Mach was the reason why Hayek wrote the manuscript on cognitive psychology (cp. De Vries 1994). Events which appear to our senses to be of the same kind may be different in the physical order, and the other way around. The relation between the sensory order of the human mind (or the "microcosm") and the physical order of external events (or "macrocosm";

³¹ More about this procedure can be found in Birner 1994a.

³² Cp. Stokman & Zeggelink 1995.

SO: 4) is the central problem of SO.

The human mind works through a continuous process of classification and reclassification of sense impressions, of the classifications formed from them, of the classifications of classifications, etc. This process is located in the "neural order" or the central nervous system, which itself is part of the physical order. The mind is continuously involved in a process of self-organization which consists of an evolutionary process that leads to an ever more complex set of classifications. The functioning of the mind consists of this evolutionary evolution.

An evolutionary framework is part and parcel of Hayek's psychology. The evolution of the human mind is part of the whole evolutionary process in which organisms, in this case man, struggle to survive:

"Our task is (...) to show in what sense it is possible that within parts of the macrocosm a microcosm may be formed which reproduces certain aspects of the macrocosm and through this will enable the substructure of which it forms part to behave in a manner which will assist its continued existence." (SO, 5.78)

One of the central theses of the book, and one of the great differences with the psychology of Mach, is that

"the sensory (or other mental) qualities are not in some manner originally attached to, or an original attribute of, the individual physiological impulses, but that the whole of these qualities is determined by the system of connexions by which the impulses can be transmitted from neuron to neuron; that it is thus the position of the individual impulses or group of impulses in the whole system of such connexions which gives it its distinct quality; that this system of connexions is acquired in the course of the development of the species and the individual by a kind of 'experience' or 'learning'; and that it reproduces therefore at every stage of its development certain relationships existing in the physical environment between the stimuli evoking the impulses." (SO, 2.49)

In other words, there are no sense data or pure facts, but all facts are embedded in a complex of relations to other facts, which we may call, in the terminology of SO, a "map". From this map, which serves as a kind of first approximation, more permanent sets of classifications is formed. Hayek calls these "models".

"It is (...) the process of multiple classification which builds the model. What we have before called the "map", the semi-permanent apparatus of classification, provides the different generic elements from which the models of particular situations are built. The term "map", which suggests a sort of schematic picture of the environment is thus really somewhat misleading. What the apparatus of classification provides is more a sort of inventory of the kind of things of which the world is built up, a theory of how the world works rather than a picture of it. It would be better described as a construction set from which the models of particular situations are built." (SO, 5.89)

However, these models are not complete representations (or duplications) of the external world. The set of models is necessarily limited. Nevertheless, the mind is capable of building representations of the physical order that help the human organism to survive. This is due to the accidental fact that the structure of the world is "redundant", to use Herbert Simon's term:³³

"It is (...) no more than a fortunate accident that the different events in the macrocosm are not fully interrelated to any significant degree, but that as a rule it is possible to base predictions of certain kinds of events on a mere selection of a totality of events." (SO, 5.90)

³³ Cp. Simon 1968.

And even though Hayek thinks that the microcosm of the mind is capable of reproducing the structure of the macrocosm of the physical order (cp. SO: 5. 78, quoted above), "there will clearly exist definite limits to which such a microcosm can contain an adequate reproduction of the significant factors in the macrocosm." (SO, 5.90).

The book concludes with a chapter in which Hayek draws the "philosophical conclusions" of his psychology. These have to do with the limits to our knowledge. Items which figure prominently in Hayek's subsequent methodology are discussed here, such as the impossibility for a cognitive system to describe a system that has a greater degree of complexity than itself (from which follows that the human mind cannot fully describe itself), and the explanation of the principle (which the mind is capable of providing of itself).

Appendix B: The influence of Hayek's cognitive psychology on his later thought.

The story of the 1920 manuscript is told on p. 62 of Hayek on Hayek. The manuscript kept sitting on a shelf until the second half of the 1940s, and was published, in English and in an elaborated form, in 1952 as The Sensory Order. About the influence of SO on Hayek's later thought, we find the author saying that

"the work on it [SO] has helped me greatly to clear my mind on much that is very relevant to social theory. My conception of evolution, of a spontaneous order and of the methods and limits of our endeavours to explain complex phenomena have been formed largely in the course of the work on that book. As I was using the work I had done in my student days on theoretical psychology in forming my views on the methodology of the social science, so the working out of my earlier ideas on psychology with the help of what I had learnt in the social science helped me greatly in all my later scientific development." (Hayek 1979: 199, n. 26)

Hayek 1982 (p. 289) mentions that in his study of scientism in the early 1940s Hayek "had been driven both to rely in some measure on the results of my unpublished work in psychology and to think further about some of the problems with which I had dealt in it." The author "seriously resumed work" (Kresge 1994: 140) on SO in the spring and early summer of 1946, when he spent two months each at the University of Chicago and Stanford. The next page tells us that Hayek's old ideas on psychology were revived by his recent work on the methodology of social science. Hayek 1982 gives some more information on when Hayek resumed working on psychology. "For the next 25 years" (after 1920; cp. p. 288) he devoted himself to economics. This would take us up to 1945. The next sentence says that "Only after I had taught for 15 years as professor at the London School of Economics ... did I feel that I could afford to take up the old manuscript and see what I could do with it." This would take us to 1945, 1946, or 1947. The next sentence again mentions "about 1946" (p. 289). Then Hayek says that he devoted what time he could in the next three years "to put a fuller statement of my views on paper." (p. 289).

All this suggests that Hayek only took up his work in psychology after he had written his first two or three articles on markets and competition. However, the similarities between his psychology and these articles are so striking, that I find it hard to believe that there was no earlier influence. And in a way, Hayek admits that there was. If I remind the reader that "Economics and knowledge" is largely about the methodology of economics, the following autobiographical passage of Hayek may be seen as an indication that Hayek started thinking about his psychology earlier than the late 1940s.

As I was using the work I had done in my student days on theoretical psychology in forming my views on the methodology of the social science, so the working out of my earlier ideas on

psychology with the help of what I had learnt in the social science helped me greatly in all my later scientific development." (LLL III: 199, n. 26)

Let me conclude this appendix by drawing the reader's attention to a curiosity that is related to SO lying at the beginning of neural network theory. When he looks back on SO after 25 years, Hayek describes the neural mechanism expounded in the book. What he gives is a description of a neural network.

"[T]he mental significance of any impulse (and group of impulses) proceeding anywhere in the central nervous system is determined by the "following" it evokes through "linkages" created by former simultaneous occurrence of these impulses at particular points.

The "followings" of all the impulses proceeding in the central nervous system at any one time are thus assumed to determine the potential or readiness of the system to do new things - internally or externally. Which of these potential neural events (toward which the system is inclined at any particular moment) eventuates would be decided by the partial overlappings of these followings which, by summation, the potential effects of those linkages would be made actual. Only where a sufficient number of impulses converged on any one neuron would it be made to "fire" and to send out impulses to hundreds of thousands of other neurons." (Hayek 1982: 290)

Curiously enough, he neither mention terms such as parallel distributed process or perceptron, nor does he refer to the literature dealing with these matters. This makes is doubtful whether Hayek himself was aware of his influence on these later developments.

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