CAPITAL AS AN EVOLVING NETWORK IN SOCIETY

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Abstract

Social network analysis and graph theoretical elements are incorporated into the Austrian Capital theory in order to capture in a better way its core concepts. In doing so, Austrian economics is opening its fort turning it into a town where economists with a certain degree of uneasiness with the neoclassical approach to economic growth or development can participate. The main result of this theoretical attempt is that: the greater the number of relational ties among firms, the more complex, and the more productive will be the underlying production process of an evolving capital network. Two examples from social network analysis about Silicon Valley and financial ties in Chicago area are presented.

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"If capital is that phenomenon which
makes market economies different ought we not to accord it a prominent
place in the education of an economist?"
Lewin 1999: 4

"Production is 'anarchistic'. " (Mises 1971: 29)

1. Introduction

This paper presents an attempt to incorporate the main insights of the Austrian Capital theory (ACT hereafter) that have survived the critics from within and without the school into a modern social network analysis setting to study the creation of capital.

This work has been motivated by Lewin (1997) words of warning that in spite of the fact that in the history of economic thought the Austrian school has been better known outside its circle for its contribution to capital theory or its business cycles' model. It is paradoxical that during the revival that has taken place in the last thirty years "this modern revival has produced relatively little work on capital." (Lewin 1997:1)

Furthermore, the topic per se of capital theory seems outmoded: a search on JSTOR for the last twelve years produced only 11 results under this title (capital theory) in the economic journals affiliated to this electronic provider. Moreover, adding the adjective Austrian produces no results at all. An alternative interpretation is that most of the topics analyzed and discussed since Bohm-Bawerk's (1889) original work have been incorporated into the economic growth models in a standard fashion, thus losing all the richness of the ACT.

Finally, this paper also tries to take seriously what Wagner and Oprea (2003) meant by referring to Austrian economics as a town rather than a fort. Also, what during

the 2005 meeting of the Society for Development of Austrian Economics its then elected president (Roger Koppl) mentioned, namely, that Austrian economists should exploit the advantages of the current turns in the economic profession to be engaged in the current debates rather than to be disengaged as pure spectators.

The paper is organized as follows. The next section presents the main insights of the ACT as developed by its most known contributors (also a subsection for the historical track of the ACT is presented). The third section introduces a 'social network analysis' and a graph theoretical model that can be valid to reincorporate the ACT on the current debates in academia. Fourth section sums up results of two examples about the application of social network analysis to Silicon Valley veture capitalists networks, and financial ties in Chicago area among medium size banks and businesses. Lastly, conclusions are summed up.

2. Austrian Capital Theory as We Know It

In this section the 'modern' Austrian Capital theory (ACT) will be presented in a summarized fashion. This, of course, does not do justice to the bulk of literature existent that, at least, since 1884 when Bohm-Bawerk (Capital and Interest: A Critical History of Economic Theory) published his first critical treatment of the issue to the present day.

Drawing on Hayek ([1941] 1975), Lachmann ([1956] 1978; 1986)[1], Kirzner (1966) and Lewin (1999) the following insights of the ACT are extracted: a) capital is

[1] See Lindahl ([1929] 1939) for an appreciation of his influence on Hayek and Lachmann on the issue of individual subjective plans and coordination, and that time is a complicated element in economic analysis.

analyzed as a production process that leads to the conformation of a structure; b) this process or the conformation of this structure takes time, or put in other words, capital is time consuming; c) disequilibrium is the initial condition (this point is stressed on by Lachmann and Lewin); d) heterogeneous capital goods can be complementary or substitutes depending upon the situation being addressed (tendency towards or out of equilibrium, respectively); e) forward-looking entrepreneurs are the driving force leading this process; f) entrepreneurial plans are based on rational expectations bounded by local knowledge; and g) ex ante[2] monetary calculation is checked ex post in order to register profits/losses.

ACT is more about the capital accumulation process taking place in time rather than a functional timeless theory on capital goods (whether physical or even human). It can be asserted that ACT is built on microeconomic premises especially. These are profit maximization by entrepreneurs, and intertemporal coordination of plans through relative prices in order to produce for the present or future. The latter is practically altogether unfolded in Menger ([1871] 1994: Ch 1) and is referred as the production of lower or higher order goods.

In order to build on Hayek (1941) process analysis and disequilibrium or disparate entrepreneurial plans was emphasized by Lachmann (1956), each entrepreneur tries to coordinate his/her plan based on expectations formed taking into account prices and the local relevant information necessary to adjust his/her plan. It is not so much the presence of a high preference to save by people that drives any capital accumulation process rather it is the entrepreneurial willingness to invest taking as an additional datum the amount of

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In fact, his influence is acknowledged by Hayek and Lachmann in their respective books on capital. Other non-Austrian influences are Jevons (1875) and Wicksell ([1893] 1954).

[2] This terminology was introduced by Myrdal ([1931] 1939)

saving available in society. Thus Hayek ([1941] 1975:331) argues that; "the amount of capital available at any moment in a dynamic society depends much more on the amount of foresight which has been shown by entrepreneurs than on current saving or "time preference"."

Kirzner (1966) deals with the intertemporal coordination within a Robinsonian setting. Where he addressed the issue of how an individual entrepreneur would make adjustments through time in order to accomplish his/her 'multiperiod plan' given some changes in external circumstances (weather, land quality, etc.). Hayek (1941: Part II) did the same in what he called 'Investment in a simple economy'; but in a more standard general equilibrium model. It is Lachmann (1956) who took off explicitly from that setting, even though building on his predecessors (especially Hayek). Thus, the problem of intertemporal coordination takes higher relevance when not only one individual multiperiod plan is analyzed but also a population of multiperiod plans elaborated by entrepreneurs and consumers unfolds.

On this setting, each entrepreneur is coordinating activities along his/her own multiperiod plan, and through market mechanisms is concurring with other entrepreneurs' plans. In order to meet their expectations entrepreneurs review their activities at every moment they may deem it necessary. Thus, entrepreneurs make ex-post comparisons to check their ex-ante plans, whenever new information over the objective facts or third's plans relevant to their own businesses is updated. If they are successful in doing this, it can be affirmed that their plans are mutually consistent (coordinated) with each other[3]. If they are not, then after every revision of the plan entrepreneurs take

[3] This is the so called dovetailing of disparate entrepreneurial plans that is found in equilibrium conditions in Hayek, Kirzner and even Lachmann's works. However, dovetailing of plans is not necessarily what

decisions to follow, adjust, or even reject their previous projects in order to keep coordinating their activities to the underlying patterns of the market determined by consumers' demand and competition.

This competitive process enables to entrepreneurs to discover through plan revision new opportunities over projects that at the onset were considered out of reach, but after a while turn out to be possible. Thus it can be affirmed that the economy is characterized by an overlapping set of multiperiod plans constituted by staggered projects along them. These are the stages of production going from the lower order goods (consumption) to those of higher order. The more capital intensive is this process, the more stages of production for higher order goods. So, at any time there is a countless number of projects under way, but at different stages of production. Nonetheless, the dynamic features of the entrepreneurial activity bring about a non-perfect system of interlocking plans where agents are doing their best for coordinating their plans but maybe without achieving full coordination at a given moment.

Specialization in each stage of production begins to appear once a higher density of population is demanding more consumption goods, and new stages of production can be adopted[4]. When plan alterations are necessary to remain in the market, the degree of substitutability of labor and capital takes relevance. That is to say the change in composition of capital is conditioned by the degree of capital heterogeneity and labor force specialized for a specific task within the production process. Each new stage of production implies a different capital composition to produce additional consumption goods. And, the increasing returns due to the addition of new stages of production are

occurs when the focus is on the process of capital accumulation of the tendency towards equilibrium, but entrepreneurial innovation to disrupt any equilibrium or even a tendency towards it.

[4] 'the extent of the market' paraphrasing Adam Smith.

related to the higher productivity of the increase in its roundaboutness (Lachmann, [1956] 1978: Ch. V). The latter is the underlying process of capital accumulation.

2.1 Historical track and modern advances in ACT

This expression of the ACT has 'modern' as an adjective because it has been modified since its original version presented by Bohm-Bawerk ([1889] 1959). First of all, Bohm-Bawerk's model has been criticized even within Austrian circles because of its objectivism as contrasted to the ubiquitous subjectivism of the Austrian school in general. Thus, Endres (1997: 147) asserts that: "Only Menger was therefore able to provide the building-blocks for a truly subjectivist theory of a 'capital-using economy' (Garrison 1985:161) later developed in the Austrian tradition by Ludwig von Mises ([1912] 1971; 1966) and Ludwig Lachmann ([1956] 1978; 1986:59-82)." These differences stems from the slightly different conceptualization of economic goods between both (Endres 1997: 146-148), but also on the different concepts about capital per se. On the one hand, Bohm-Bawerk stressed on the material or physical characteristics of capital and Menger; even before Bohm-Bawerk's critics outside the Austrian school; did not abandon the subjectivist approach in defining capital[5], on the other hand. In addition, there were early debates at the turn of the twentieth century related to Bohm-Bawerk's model. One of them very known within Marxist theorists about surplus-value; and another one against J. B. Clark's homogenization of capital goods or the view of capital as a 'fund'.

Between 1930 and 1940 there was again other series of debates about the ACT but this time, Hayek (1934a; 1936) and Machlup (1935) on the Austrian side whereas Knight (1933) was on the other. What Knight did was to revive the old debate between

[5] See Hayek (1934b) for a comment that suggests this.

Clark and Bohm-Bawerk almost forty years before. According to Hayek (1936) even the same Clark's arguments were used by Knight, but Hayek and Machlup considered that the critique of Bohm-Bawerk's 'average period of production' concept was to some extent correct and rightly focused. What this next generation of Austrian economists considered completely wrong was the 'mythological' solution suggested by Knight and Clark, namely, that the capital has to be analyzed as a 'fund' where capital goods are homogeneous. Here lies, to some extent, the origin of the difference between what thirty years later would be known as the Cambridge controversies on capital, with Robinson (1953-54) and Sraffa (1960) on the British side, and Samuelson (1962) and Solow (1955-56) on the American one.

Clark and Knight's static argument was basically that capital is a homogenous fund that reproduces itself. Also, time rather than to be analyzed was taken away from capital theory. Thus, there was no a complex structure of capital only a theoretical approach that leads to the smooth depictions of capital functions. And a derivative conclusion of this was that the interest rate is determined by the productivity of capital because production costs are more relevant to explain this phenomenon (Huerta 1998:92).

It is remarkable that Bohm-Bawerk predicted that underconsumption theories would prevail if Clark's view earned enough acceptances, and this was what actually happened with Keynes and economists of a similar way of thinking. Thus, Bohm-Bawerk (1895:137)[6] wrote: "When one goes with Professor Clark into such an account of the matter, the assertion that capital is not consumed is seen to be another inexact, shining figure of speech, which must not be taken at all literally. Any one taking it literally falls into a total error, into which, for sooth, science has already fallen once. I refer to the

[6] Cited by Huerta (1998).

familiar and at one time widely disseminated doctrine that saving is a social evil and the class of spendthrifts a useful factor in social economy; because what is saved is not spent and so producers cannot find a market". And right on the tails of the dispute Wilson (1940:169) on a related subject mentioned that; “The outcome of recent trade cycle controversy has been, on the whole, a victory for the underconsumptionist school.”

In an issue of the Journal of Economic Perspectives, while covering the Cambridge controversies, a call for a greater attention to the importance of the capital theory was made by Cohen and Harcourt (2003:210); “The Cambridge controversies were the last of three great twentieth-century capital theory controversies. Earlier controversies occurred at the turn of that century among Bohm-Bawerk, J. B. Clark, Irving Fisher and Veblen and then in the 1930s among Knight, Hayek and Kaldor.” In fact, Lachmann so much as Hayek acknowledged that their own efforts clarifying some flaws in the previous theories and improving upon them do not answer all the questions posed by them on capital theory. Cohen and Harcourt (2003:211) on the history of the debate cited the following passage in Solow (1963:10) “when a theoretical question remains debatable after 80 years there is a presumption that the question is badly posed—or very deep indeed.” that shows how breadth has been the scope of the discussion on this topic but how little depth economists have explored. Adding up all the years since the original capital controversies, a total of 120 years has elapsed, and as they asserted questions about capital theory are ‘very deep indeed’.

Heuristics and domain (Bellante and Garrison 1988) assumptions on capital have taken an important role on this debate. First of all, Bohm-Bawerk’s circles were an attempt to capture the temporal dimension of the production process. Bohm-Bawerk’s

followers and critics did not get along with this graphical tool, nonetheless to some extent conveyed some of his ideas to other economists. Hayek inspired by Jevons' investments triangles and unsatisfied by Bohm-Bawerk's circles established what is known as 'Hayek triangles'. This is important because the way that the argumentative prose has been used developing ACT[7] is deeply related to these 'domain' assumptions. As a matter of fact, Hayek, who introduced his triangles in his 1931 lectures at LSE (and turned out to be published as Prices and Production), took again several chapters on his book *The Pure Theory of Capital* (1941) in order to develop and explain how this three-dimensional image could help to understand his (or the Austrian) capital theory better by other non-Austrian economists.

On the other hand, Lachmann (1956) and before him in a more focused fashion Machlup (1940) introduced the institutional setting on which capital was developed, i.e. financial institutions being the most important of them the stock market. Thus, forward-looking entrepreneurs do not create capital in a vacuum in actual market economies rather there was a parallel institutional craftsmanship in western societies along with the accumulation process of capital, mostly known as industrialization. Thus, banks, stock markets, credit and money markets in general were shaped and gave rise to specific organizational structures throughout western development.

The international world's fairs that were common during XVI-XVII centuries in Europe established regional centers where entrepreneurs and businessmen made deals with one another. The mercantile law has its origins there. In the same way, in modern

[7] And the same is experienced using the supply-demand cross typical in economics, phase diagrams in growth theory, and so on.

developed societies stock markets still play the major role in financial markets through which capital is valued by investors and transferred from one to another.

According to Sarasvathy (2001)[8] entrepreneurs in the U.S. engage in entrepreneurial adventures networking their friends and related people, rather than just to make their business plans or even before doing any market research about their products. This is the difference between what she calls 'effectual reasoning' in contrast to the manual kind of reasoning in business called 'causal reasoning'. Thus, it is my contention that through these 'social networks' capital is created in modern societies. The next section will develop a network model for the ACT.

3. A Social Network Analysis for the ACT

Social networks or the 'theory of network analysis' is a concept developed in sociology and anthropology around late 60s and early 70s (Watts 2003[9]). Some of the seminal contributors are: Granovetter (1973, 1976) and H.C. White (1976a, 1976b). Nonetheless, some of the basic original tools; e.g. graph theory; were created by mathematicians as early as 1736 (Watts 2003:28) when Euler was commanded to analyze the problem of crossing seven bridges only once in Konigsberg. Nowadays, social networks have captured the attention of economists; e.g. Jackson and Wolinsky (1996); and even physicists such as Strogatz (2001) and Watts (1999, 2003). Additionally the range of applications covers social issues, for example: scholars', terrorists' and actors'

[8] This is a point that Richard Wagner has also stressed. See also Chamlee-Wright and Myers (2008).
[9] All the references given here are from Watts 2003.

networks, small world problems (every person is separated, at least, from any person in the world by six persons), and organizational structures in the market (Burt 1992, Swedberg 1990, and rather more about graph theory Potts 2000).

Before to present the network schema on the emergence of capital the following question will be addressed; what is the relevance or 'value added' of this type of methodology in Economics? First of all, this approach will help to grasp the organizational structure of the market in its static internal appreciation. Secondly, it will illustrate the evolution or dynamical change of these market structures. This is what Watts (2003: 54-55) calls 'dynamics on the network' in contrast to the 'dynamics of the network'. In other words, social networks analysis allows a more concrete understanding of the concept of 'spontaneous order' in the market as developed by Hayek (1937, 1948, 1976). Thus, it will give economists (or sociologists) an analytical tool to nail down some of their typical arguments about the functioning of institutional settings in society. For instance, specific cases about coordination among entrepreneurs through networks can be studied such as the Silicon Valley development (Castilla et. al. 2000, see section 4).

Moreover, Swedberg[10] mentioned that network theory is perhaps the most important tool in these days in economic sociology, and what is especially relevant for this paper is that according to him (a contributor to this subject) a small number of applications to macro structures have been accomplished. The latter seems to be a result of the concentration of people working on this subject on the 'small world' phenomenon.

[10] Lecture presented at the Workshop in Philosophy, Politics, and Economics on August 31, 2005 at George Mason University.

3.1 Creating Capital through Networks

Entrepreneurs apply their forward-looking capabilities to make prospective plans[11]. They take actions based on their cognitive interpretation of the market information that results from people interaction and it is expressed by abstract symbols such as prices for outputs and inputs. In order to give concretion to their plans entrepreneurs organize firms to take advantage of the economies of scale because of the reduction of transaction costs (Coase 1937) to make contracts with inputs' providers and buyers/clients.

These firms relate each other creating commercial ties to coordinate their plans to produce capital goods that will be incorporated along different stages of the production of consumer goods. Thus, firms create relational ties between them as long as it is profitable and technologically efficient to do so. These dyadic relations evolve through time[12] not only into triadic relations among firms, but mainly to a dense network of capital producing firms and financial organizations, comprised by a heterogeneous group of workers and physical assets. This 'dynamics of the network' give rise to the emergence of polycentric structures whereby firms interact (on the network) constantly with each other to reduce transaction costs, creating reputation for credibility in contracts. Thus, the greater the number of relational ties among firms, the more complex[13], and the more productive will be the underlying production process (see 3.2 for a mathematical (but

[11] See Shackle (1986) on the role of imagination within entrepreneurial planning, articled published on Kirzner and Lachmann 1986.
[12] Here insights on market process theory, quintessential to Austrian Economics, are being incorporated within a network analysis. Thanks to Jenny Dirmeyer for calling attention on this point.
[13] The degree of connectivity, i.e. the complexity of the network creating capital can be compared with concept of the deepening of capital (Hayek [1941] 1975:286) that is capital growth along its time dimension.

static) presentation of this theorem and the use of graph theory and computer simulation displays). Complexity here means a dynamically efficient process of production (Potts 2000) whereby the advantages of the particular degree of connectivity of the network that surrounds any firm is added to those pertaining to the global degree of connectivity across the whole market (these are the so-called hyperstructures or hypergraphs). Put in other words, bonding relational ties in developed (i.e. capital intensive) societies are embedded into a network of bridging relational ties that are institutionalized by means of publicly known organizations such as: stock markets, banks, credit bureaus, etc. In short, capital accumulation is created through a hyperstructure comprised by different levels of networks representing firms producing consumer goods, firms producing different kinds of capital goods, firms providing the financial means demanded by those, among other related. Furthermore, a network facilitates the process of acquiring information not necessarily public to entrepreneurs who are always trying to look ahead anyone else's, but rather learning by trial and error.

Within the process of capital accumulation some entrepreneurial plans have to be revised due to unexpected changes (Lachmann [1956] 1978:Ch. 3) in external circumstances (e.g. weather) or in prices that were misinterpreted by entrepreneurs. Thus, there is no market equilibrium or a mutual consistency of plans, rather an ongoing process of adjustment and revision of the plans. The flexibility of any plan depends upon the degree of complementarity and substitutability of capital goods, the time horizon relevant for adaptation, and the expected changes in key relative prices for this process such as interest rates. Thus, ex-ante monetary calculation during the stage of planning is

checked ex-post to register profits/losses that leads to a constantly changing variety of entrepreneurial plans.

Those entrepreneurs who are not successful doing adjustments after plan revisions allow that better qualified entrepreneurs interpreting market information can accomplish their plans successfully. In this fashion, new technologies incorporated into new/old products take place in the market. Also, entrepreneurs, both successful and unsuccessful ones, learn to interpret better the market information retrieved by the different phenomena of bankruptcy, innovation and entry.

This is what Lachmann ([1956] 1978:48)[14] called 'reshuffling' or 'regrouping' of capital, that is the capital combinations required after the revision of plans due to unexpected changes in relative prices. How substitutable is a capital good is especially relevant here because this is what determines if it can be easily adapted for being used on a different entrepreneurial plan that turned out to be more successful interpreting the new conditions of the market.

3.2 Graph theoretical model of the emergence of capital

Let G=(V,E) be a graph with a vertex set V which is a set of firms, and an edge set E which is a set of pairs of firms that through combination of their resources are aiming at to create a new technology. It should, also, be obvious that this exchange only takes place if both firms engage in a mutual advantageous trade interaction (e.g. prices

[14] Network kinds of reasoning seem to be followed by Lachmann in this book, as well as by Hayek in his relevant work on capital. For instance, "We may regard the price system as a vast network of communications through which knowledge is at once transmitted from each market to the remotest corners of the economy" (op. cit.: 21) and later; "Capital goods are merely the *nodal points* of the flows of input (of labor and other capital services) which they absorb, and of output (of intermediate or final products) which they emanate." (op. cit:58, his emphasis). This latter view is developed is this paper.

agreed upon by both parts). So long as every firm does not get involved in trade with everyone else, a complete graph is not present. However, the graph is connected, which is to say that if any pair of firms stops doing business other firms may be affected, whether positively or negatively.

Every firm Vi is modeled, following Potts (2000), as an economic agency (hetero economicus) so that:

Firm Vi: $<\Omega^{+} : \Omega^{-}> <\pi^{+} : \pi^{-}>$ <R: T> <X: P: Y>

Where R is the set of owned resources, T is the set of owned technologies[15]. The *internal* set of rules <X: P: Y> includes a set Y of decision rules, and a set X of rules' interpreter. The set P is more complicated to explain, Potts (2000) denotes this set as 'schematic preferences.' But actually he is applying the concept of 'working memory' as explained in evolutionary computational models (Gilbert and Troitzsch 2005), that means a learning classifier system to modify rules to a new environment. The combination interactive set $<\Omega^{+} : \Omega^{-}>$ is one of the criteria to establish a connection between any two firms, by this criterion the technological advantages of carrying out the action to merge technologies is assessed. The second criterion for interaction is $<\pi^{+} : \pi^{-}>$ which is the profitable analysis of having a commercial relation with other firm. Both criteria are *external* decision rules, as opposed to the internal ones mentioned initially. That is to say, the internal set of rules serves to model the interaction between an agent and its environment, whereas the external set deals with the interaction between agents.

[15] This is a simplification of the set modeled as a technology string, which is $E= <S(A)^{0},\ldots,S(A)^{i}>$, by Potts (2000). Here R is used instead of V and T instead of E, because V is a firm and E a new technological combination in this setup.

In Figure 1 a graphical representation is provided for the case of an old-fashioned lead pencil (Read 1999).

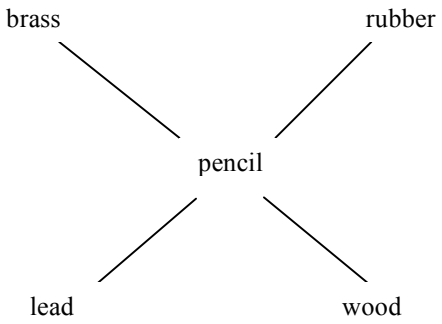

Figure 1: A simplified graph for a lead pencil's production.

Here, of course, this simplified sketch for Read's example about the complexity of the production process, only shows the industries (e.g. more than one firm may provide wood) that are more directly related to the fabrication o a lead pencil. But one also can think of a specific firm to manufacture pencils with its specific suppliers. Thus, in this case we have Gp= {V(pencil, wood, rubber, brass, lead); E(pencil:wood, pencil:rubber, pencil:brass, pencil:lead)}[16].

Now I will introduce the following theorem: *the greater the number of connections, the more complex is the underlying production process of an economic good* (see Figure 2). It could be necessary to recall that an economic system is dynamically efficient if its connective structure is more complex, and also that the object of choice in evolutionary economics is the selection of a set of connections (Potts 2000: 106-107). Moreover, the tendency towards complexity implies that the economic system is achieving a dynamic optimum region in the state-space.

[16] Figure 1 is not an attempt to capture all the complexities involved in the actual production process of any kind of pencil.

In graph theoretical terms, an underlying graph G for a complex production process is a λ-edge-connected graph with λ+1 technologies/connections which edge-connectivity λ(G) is the smallest value of λ for which the ultimate product (e.g. a pencil) can be available for consumption[17]. Imagine a pencil without a lead, or a car without tires, and so on. Thus, formally it can be said that; the greater the value of λ, the greater the complexity, and the more dynamically efficient is the production system.

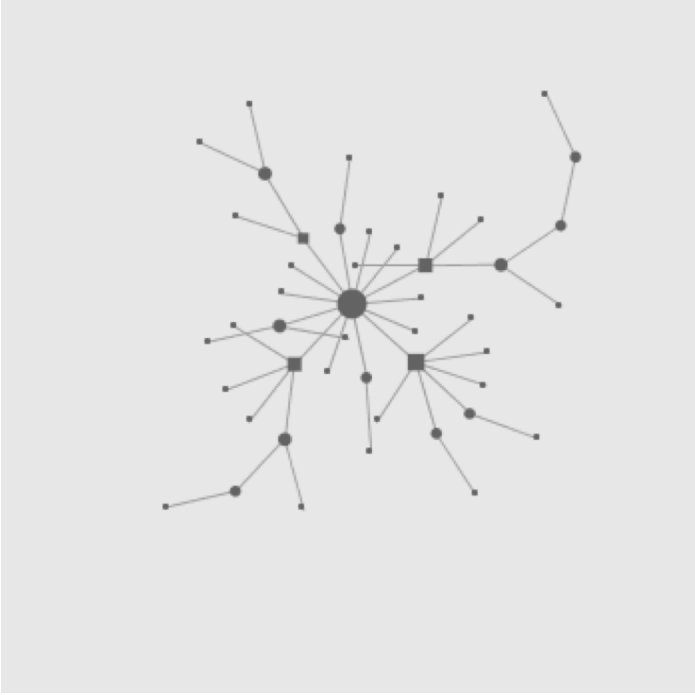

Figure 2a: simple structure. 100 periods, higher connected nodes are of a major size.

[17] In graph theory is also common the concept of k-connectivity k(G) where k stands for each vertex through which the graph is at minimum connected. Karl Menger's theorem is usually applied to determine the number of k and of λ. See Beineke, L. W. and R. J. Wilson (1997).

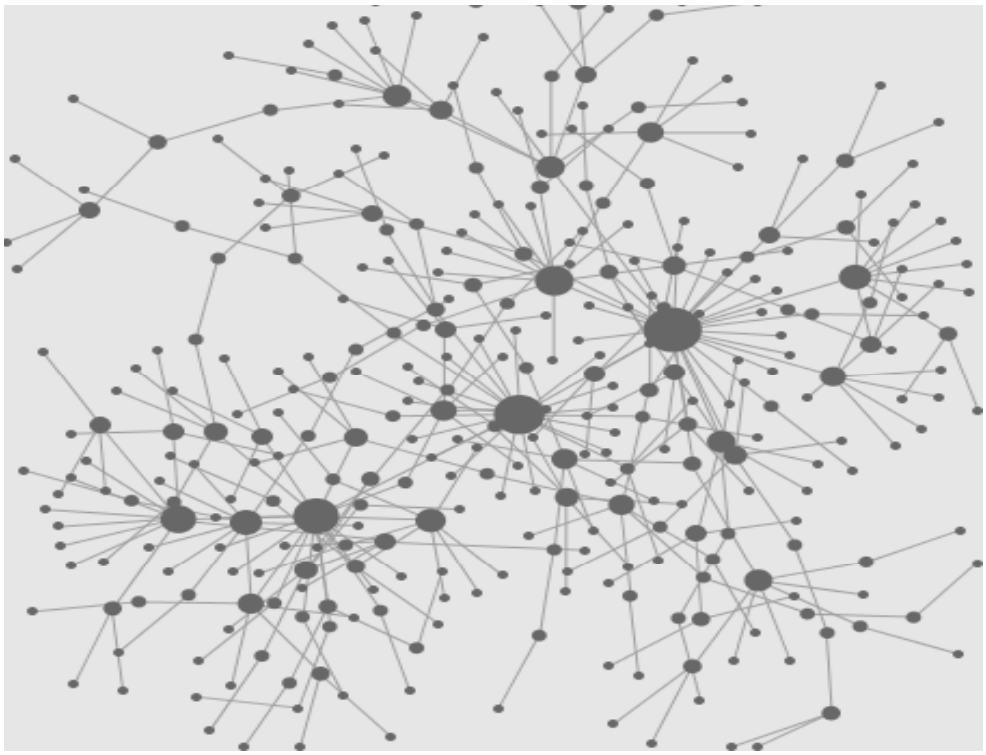

Figure 2b: complex structure. 1000 periods, higher connected nodes are of a major size.

4. Two Empirical Cases

In this section two examples about capital creation through networks will be presented. Both reflect to a great extent the ideas developed here. These two examples were elaborated by Castilla et. al.(2000) and Uzzi(1999).

The first work is about Silicon Valley and how the development of that region is generated through the networks of venture capitalists, educators, engineers, lawyers, trade groups, and so on. Regarding the conformation of technological firms a special focus is given to employees and referees, managerial, and information networks that are generated and transmitted through different links or channels among firms.

For instance, Castilla et. al. call attention to the fact that:

> "Extensive labor mobility creates rapidly shifting and permeable firm and institutional boundaries and dense personal networks across the technical and professional population. The ability of Silicon Valley to restructure itself when conditions change through rapid and frequent reshuffling of organizational and institutional boundaries and members (…"recombinant" process) is one of the factors that underlie the dominance of Silicon Valley…" (pp. 220)

Their analysis show how the creation of capital in Silicon Valley is benefited and fostered by the positive externalities created due to the high degree of density and the openly competitive environment among different networks of educators, venture capitalists, and others people related to a given firm. An intense competition and high mobility of resources allows for a fast rate of learning of adaptation to the new conditions of the market. One important characteristic that they pointed out is the fact that much of the know-how or informal knowledge produced by this interaction among technological firms remains local.

Using techniques of social network analysis and data collected by journalists they are able to trace; from 1947 to 1986; the evolution of the network of firms, managers, educators and so on. That contributed to the beginnings of projects as Intel and the like. Those individuals or firms with a high degree of centrality (connected to a lot of others) and those that play the role of 'crucial linkage' to reach others are discovered. Thus, entrepreneurial spirit, willingness to support innovative ideas, but specially networks externalities are the key elements identified by them to the great development of Silicon Valley.

Studying the network from which IPOs (data from 1999) are originated in Silicon Valley. They found[18] three different kinds of organizations that interact and collaborate to give birth to a new enterprise. These are; investments banks, law firms, and accounting

[18] See figure 11.1 in Castilla et. al. (2000).

firms. The issuer firm is not portrayed. There is a tie between any two firms (from the same or different industry) whenever both are involved in the same IPO. The length of the line also conveys relevant information namely; it is inversely proportional to the number of coparticipations. Therefore is a proxy for the strength of the tie; the more coparticipations, the stronger the relationship (the shorter the link).

The main result of this kind of work according to the authors is that a particular kind of network; defined by centrality and degree of connectivity; determines particular outcomes. In other words, what kind of relationships exists among the actors of any network. In a posterior work by Castilla (2003) he compares the degree of connectivity or density of the network of venture capital firms in Sillicon Valley to the one in Route 128 (Massachusetts). He found that the higher number of projects and amounts of money invested in California are a consequence of the higher connectivity among firms through different industrial sectors and within each of them.

Secondly, Uzzi(1999) carried out an analysis of the effects of social embeddedness of networks in corporate financial dealings. An important contribution of this paper is the triangulation between social network analysis, statistics, and original data collected through field research. The sample included 2400 small or medium size companies and eleven medium size (less than 500 employees) banks in the Chicago area. His focus is upon the credit networks or the bank-borrower ties and their effects on the amount and cost of loans obtained. As a matter of fact, the first pair of hypotheses is: if bonds or social attachments created (and the longer it is this relation) among managers and bankers increase the probability of getting a loan and if given this the cost will be

lower. Data from the fieldwork pointed out that bankers and managers do care about how to establish a social relationship with one another beyond the cold numbers. Because to get to know to each other gives them information that is not easily found in figures, and increases the degree of trust in their relationships.

The other pair of hypotheses tested by Uzzi is: the likelihood to get financing increases if a firm has access to a mix of embedded and arm's length ties. In other words, if a mix of bonding and bridging social relationships in different networks is important to arbitrage opportunities and reduce search costs. The subsidiary hypothesis here is if costs of financing are lower if a firm has access to these two kinds of social networks. Another way to put this is that if a firm only has been focused on cultivating only one kind of these networks' ties (bonding or bridging) it will be less successful getting loans and reducing the costs per loan.

An important concept explored by Uzzi is related to this mix of bonding and bridging networks what he referred as to 'network complementarity'. In his own words;

> "Networks high in complementarity produce premium outcomes because the features of different ties reinforce one another's advantages while mitigating their disadvantages." (pp. 491)

The econometric tests yield these results: the social network bonding ties did not affect the probability of a given firm to get loans, but it does affect the price or interest rate of the loan. And the latter is in agreement with field data. In regards to the tests about network complementarity these point out that these kind of combined network ties do produce optimal benefits relative to networks only of one type for a firm.

These two examples have been very useful to give concrete representations of the model that has been sketched out here. The positive or negative externalities of different kinds of networks under technological and financial contexts, that have been described are empirically relevant and point out and important line of research that is still dominated by sociologists. Economists (especially those with a strong Austrian influence) can contribute twofold by engaging in this research because they can bridge the network between economic and sociological concepts applied in network analysis. But also by placing on the current topics in economics again the relevance of the Austrian theory of capital and its concepts about heterogeneity and time consuming production process.

5. Conclusions

The main objective in this paper has been to incorporate the core concepts of the Austrian Capital Theory (ACT). Namely, time consuming process, complementarity and heterogeneity of capital goods, etc.; into network analysis. In order to achieve this goal tools from 'social network analysis' and graph theory have been applied. Two examples based on research by sociologists about Silicon Valley's venture capitalists and financial networks in Chicago area were presented as prototypes of the kind of a possible avenue for empirical work. In doing so, it is expected that ACT may be again a highly discussed topic into the current debates about development, economic growth, and business cycles. Lachmann and Hayek's ideas about prices as information mechanisms, capital goods as part of a network, and complexity of the market phenomena, are altogether convenient to undertake this endeavor.

The bottom line is that the greater the number of relational ties among firms, the more complex, and the more productive will be the underlying production process

Network models will allow assuming population or a multifarious Robinsonian economy with non-completely informed agents who organize their plans creating organizations to carry out them, rather than a (one-)Robinson economy. This can be done using agent based models developed by simulation and computational techniques. Moreover, empirical studies based on field research or even historical examples of entrepreneurs creating capital through time and structuring ties with their providers, consumers, and even their competitors, can be a further step in this line of research. Thus, process phenomena in the market can be better understood.

For Austrian economists is important to notice that advances in ACT or their business cycle theory need to be improved beyond what Hayek, Rothbard, Mises contributions. A detailed reading of their books open more questions than giving ultimate answers for all the complex problems they addressed during their time. Pursuing this goal will mean to collaborate very close to related economists who are trying to apply non-standard models to market phenomena.

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