The Structure of Society as a Determinant of the Rate of Economic Growth

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Abstract: The rate of growth is found to depend on the structure, or more specifically the size, degree of connection, efficiency, and `community spirit' of the network of relationships that exists within the economy. This structure, which is assumed to be exogenously determined, is important because it determines how effectively news of productivity increasing technological change spreads throughout the economy. The extent to which exclusive groups or cliques exist within the economy is also found to be important, although they are not necessarily detrimental. The model provides an explanation of why growth rates vary between economies and between different regions, modern and informal sectors, classes and ethnic groups within an economy. It also suggests that there might be a policy link between social planning and economic growth.

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> [A] country's potential for rapid growth is strong not when it is backward without qualification, but rather when it is technologically backward but socially advanced (Abramovitz (1986), p. 388).

1. Introduction

The model presented in this paper establishes a link between the structure of the network of relationships that link the agents in an economy together and the rate of growth of that economy. The structure of the network is important because it determines the extent to which new knowledge, the driving force behind productivity growth, spreads throughout the economy. Intuitively, the greater the number of agents who get to hear about a productivity increasing technological change, the greater the potential impact of that change on the aggregate output of the economy. In earlier models of knowledge accrual and economic growth it is always assumed that knowledge is a public good. Indeed, this characteristic of knowledge is central to this class of models. However, the questions of how knowledge becomes public and to what extent it becomes public have only partially been addressed. In each case the answer relates to the network of relationships between agents.

Relationships between economic agents have rarely been a topic of analysis for economists.[1] Sociologists, on the other hand, regard the study of relationships as vital for understanding human behaviour and the development of societies as a whole. When conducting empirical analysis they distinguish two types of data, attribute and relational.[2] Attribute data are information on the attributes of an individual, an economy or institution

[1] There are notable exceptions, one of which is Williamson (1979).

[2] See Scott, J. (1991) 'Social Network Analysis: a Hand Book,' Chapter 1 for a more comprehensive coverage of these terms. For a recent survey of social network analysis, see Galaskiewicz and Wasserman (1993).

(e.g., the income of an individual is an attribute of that individual, the rate of growth of an economy is an attribute of that economy, and the efficiency of an institution is an attribute of that institution.) Such data can be either quantitative or qualitative. Relational data are information on the links between individuals within an economy or institution, between individuals and institutions, or even between economies. Again, this data can be quantitative (how many relationships) or qualitative (what type of relationships and between whom). Economists are familiar with the network of relationships that make up the market system. However, when analyzing this system they tend to focus on the attributes of the agents within the network and the goods they exchange (including their prices) rather than on the relationships between the agents. This is primarily because of the special nature of the market system and its coordinating price mechanism. In a perfect market system, agents are anonymous and one-to-one relationships either do not exist or do not matter.[3]

A notable and relevant example of how economists focus on the attributes of agents rather than the relationships between them relates to the quotation at the start of this paper. When expanding on the notion of social advancement or 'social capability' (following Ohkawa and Rosovsky (1973)), Abramovitz (1986) named three elements. At the micro level he equated social capability with the concept of human capital. At the macro level he considered the qualitative nature of political, commercial, industrial and financial institutions to be important. Finally, Abramovitz cited Olson (1982), who identified defeat in war with the sweeping aside of old vested interests and the consequent clearing of the way for new structures and modes of operation. Turning this around, Abramovitz' third factor was the degree of 'openness to competition, to the establishment and operation of new firms, and to the sale and purchase of new goods and services' (pg. 389). Many other authors, intent on explaining economic growth, have analyzed these and other aspects of social capability, but, like Abramovitz, all of them have focused on the attributional aspects of social capability.

There is a relational aspect to social capability that is yet to be analyzed by economists interested in economic growth. There are many goods exchanged in an economy for which

[3] See Ouchi (1980), Bradach and Eccles (1989) and Powell (1990) for discussions on the limitations of the price mechanism and the need for trust generated through long-term relationships.

the setting of a price is difficult. Where this is the case the relationships between agents who are party to the exchange become important. One good for which price setting is problematic is knowledge. While it is true that the publication of new knowledge is important, only a very small proportion is published. More often knowledge is exchanged between people who know one another. When knowledge flows between institutions, such as firms, it is again because there are relationships between individuals within those institutions. The degree to which the structure of the network of relationships within a society allows knowledge to flow to those who can make use of it is an important aspect of that society's capability with respect to the generation of growth.

In Section 2 I look at the role that knowledge plays in the new endogenous growth models, specifically those of Romer (1986 and 1990), and at the processes by which knowledge becomes public. In Section 3 I introduce the concept of an information network multiplier and explain how it relates to the structure of an information network. Two network structures, as well as the effect of breaking the population up into cliques, are analyzed. 'Clique' is another term borrowed from social network theory. Here, it is defined as a sub-group of a population that is characterized by a dense network of relationships within its bounds and significantly fewer or no relationships traversing those bounds. Also, in this section I explain the connection between the information network multipliers and the semi-public nature of knowledge. Section 4 contains a growth model that highlights the effect of the structure of the networks within the economy on the rate of growth. Section 5 briefly looks at the welfare and policy implications of the model. Section 6 presents a few examples illustrating how the theory might aid our understanding of why growth rates differ between economies and between different groups of agents within economies. Section 7 links the theory developed here to the literature on social learning. In Section 8, I reconsider the assumption that networks are exogenous and looking briefly at the effect of weakening this assumption to allow some aspects of network structure to be determined by rational choice. I conclude in Section 9.

2. The Role of Knowledge in Economic Growth

The simple growth model that I develop below is closely related to the one Romer (1986) presented in his paper 'Increasing Returns and Long Run Growth'.[4] Consider a population of N symmetric firms with the production function

$$y_i = L_i^{1-a} k_i^{a} K_i^{b} \tag{1}$$

where y_i is the output of the ith firm and L_i is the labour employed by the ith firm. The term k_i represents firm specific knowledge which is assumed to be quantitatively the same for all firms while being distinct with respect to its content. Finally, K_i is the general level or overall stock of knowledge as perceived by the ith firm. Knowledge may appear in aggregate form in each firm's production function because it is non-rival. The N firms are symmetric in that they quantitatively have the same y_i, L_i, k_i and K_i, whereas they are distinct with respect to the content of both their specific knowledge, k_i, and their perception of the overall stock of knowledge, K_i.

This production function corresponds to the one on page 1015 of Romer's (1986) paper except that, here, a Cobb-Douglas technology is assumed and for simplicity only two inputs, labour and knowledge, are considered. Also, for reasons that will be explained below, whereas Romer assumes that K_i is the same for all i with respect to both quantity and content (K with no sub-script appears in his model), here, each firm's K_i is different with respect to content (but the same quantitatively). The production function is homogeneous of degree one with respect to labour and firm specific knowledge but exhibits increasing returns when the overall stock of knowledge is included. Despite the increasing returns, this production function is consistent with a decentralized equilibrium because firms treat the overall stock of knowledge as exogenous.

[4] It is even closer to the simplified version of Romer's (1986) model that was presented in a lecture by Dr. P. Aghion, at Nuffield College, Oxford, March, 1994.

The central questions in this and the next section are: 1) how does knowledge become public and 2) what is the relationship between firm specific knowledge, the general level or overall stock of knowledge and a particular firm's perception of that overall stock? In Romer's (1986) model the overall stock of knowledge, defined as the sum of all the firms' specific knowledge, enters the production function, i.e.,

$$K_i = K = \sum_{i=1}^{n} k_i = Nk_i \qquad \textit{for all } i \tag{2}$$

Each firm's perception or comprehension of this overall stock of knowledge is partial, for each firm keeps their specific knowledge partially secret. It is for this reason that both k_i and K and not just the latter appear in the production function. In addition, each firm's partial perception of the overall stock is the same with respect to both quantity and content. So, there is assumed to be some mechanism by which knowledge diffuses evenly throughout the economy as soon as it comes into being. In Romer's later paper (1990), a similar mechanism is assumed to exist except this time comprehension is complete. Researchers have at their disposal the entire stock of knowledge, in the form of existing designs, when producing new designs. When knowledge is defined as designs deserving of a patent and freely accessible for citation by all, the assumption that knowledge diffuses evenly throughout the population is plausible.[5] However, not all additions to the stock of knowledge can be characterized as designs deserving of a patent. This is particularly true in developing countries where there are often no patent laws and where R and D is far better characterized as the importation of information from external sources rather than as domestically based research.

How then does knowledge become public and to what extent does it become public? It seems plausible to suggest that the most common way for information to become public is through networks of interpersonal and inter firm relationships. Information might be shared

[5] Even for the R and D business in the US there is evidence to suggest that information flows between research establishments via such routes more frequently and/or faster than it passes through the Patent Office. See Jaffe, Trajtenberg and Henderson (1993), "Geographical Localization of Knowledge Spillovers as Evidenced by Patent Citations."

by many agents at formally arranged meetings or might spread from one agent to another through a series of one-to-one meetings. In either case an agent with an initial endowment of knowledge will, as a result of being part of a network, be able to swap it for other knowledge and, bearing in mind that knowledge is non-rival, end up with significantly more than that with which she started.

To emphasize that I am solely interested in the role of these networks in the publicizing of knowledge I refer to them as information networks. However, networks do not exist for the sole purpose of sharing information. They may be social in nature or they may correspond to groups who have come together to protect vested interests, to offer mutual security, or for some other purpose. These ideas are closely related to the idea of exogeneity with respect to information networks. An information network is exogenous when its structure and workings are the consequence of imposed rules or choices made without reference to the value of the network as a provider of information. In this paper the focus is on exogenous information networks.

3. The Structure of Information Networks and the Information Network Multiplier

Consider a network with m symmetric members. All the members have a package of knowledge, k_i, that is specific to them. The packages of knowledge are quantitatively equal while being distinct with respect to content. Each member's specific knowledge is considered to be of equal value by all members. Of their specific knowledge they are willing or able to share a proportion, v. This proportion is generally less than one, either because some information gets lost in the telling or because the owner wishes to retain some for her sole personal use. The more efficient the network or the greater the 'community spirit' among the network members, the closer v is to 1. Through the process of networking, each member, while retaining her specific knowledge, gains further knowledge from her fellow members. Her knowledge is multiplied. So, the relationship between a representative member's specific knowledge and the total amount of knowledge she ends up with, K_i, is the product of her specific knowledge and a factor that I call the information network multiplier, H(B,m,v).

(3) $$K_i = H(B,m,v)k_i$$

The value of this multiplier depends on m and v, which have already been defined, and on B. B is the number of other agents with whom the representative agent has a direct link. Sociologists refer to this as the 'degree of connection' of a network member (see Scott, J. (1991), page 70). B, m and v define the structure of the information network, which is then summarized in the information network multiplier. The assumption that agents are symmetric relates not only to their attributes, but also to their relationships, i.e., it is assumed that v and B are the same for all agents. For this reason the network itself may also be described as symmetric.[6] B, m and v are all exogenously determined.

The first thing to note about the relationship in Equation (3) is that the more specific knowledge each agent in the network has the greater each agent's total knowledge holding. A marginal increment in agent's specific knowledge leads to an increment in their total knowledge equal to the multiplier.

Another way of thinking about this process is to break K_i up into the member's specific knowledge and the additional knowledge she gains through the network, K_{+i}.

(4) $$K_i = k_i + K_{+i} = k_i + h(B,m,v)k_i$$

where h(B,m,v) is the net information network multiplier and is equal to H(B,m,v) minus 1.

The effect of B, m and v on the multipliers depends on how we characterize the network. Below, I look at two types of symmetric network, a formal club or association and an informal network.

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[6] Because of symmetry, B is also closely related to what sociologists refer to as the 'density' of the network. The density of a network is defined as the number of links that exist between the members of the network divided by the maximum possible number of links. In this model of a symmetric network the density of the network equals B/(m-1). Note that sociologists do not usually impose symmetry on the networks that they analyze.

3.1 A formal club or association

A formal club or association might be characterized by a group of members who meet all at once. Each member comes to the meeting with the information that she is prepared to share, vk_i and goes away with the sum of all the bits of information that all the members are willing to share. In this case the network multiplier is

$$H(B,m,v) = 1 + (m-1)v \tag{5}$$

The first term on the right hand side of this equation, 1, reflects the fact that the representative agent retains her specific knowledge. This term is eliminated in the net multiplier. The second term states that the representative agent gets a proportion v of the specific knowledge originating from the other m - 1 members of the network. Note that B does not appear on the right hand side of this equation. This is because through the meetings each agent has a direct link with all the other agents in the network, i.e. B = (m - 1). Turning to the first and second order partial derivatives, the larger the club the greater the multiplier, $H_m = v > 0$. This relationship is linear so $H_{mm} = 0$. Increasing the efficiency of the club at conveying information or the degree to which the agents are prepared to share their knowledge also has a positive effect on the multiplier, $H_v = m-1 > 0$, and again this relationship is linear, $H_{vv} = 0$. The second order cross partial derivative is $H_{mv} = 1$ suggesting a complementarity between the size and efficiency of and community spirit within the club.

3.2. An informal network

This network might be characterized by a series of bilateral interactions, with each member prepared to share a proportion, v, not only of their own specific knowledge but also of all the other knowledge they hear through the network. So, if you hear it from the horse's mouth you get v of the story, if you hear it from a friend of the horse you get v^2 of the story, if you hear it from a friend of a friend of the horse you get v^3 of the story and so on. Sociologists refer to the power to which v is raised as 'the length of [the] path' between the two network members (see Scott, J (1991), page 71). It corresponds to the number of passes a piece of information goes through to get from the originator to the representative member. Note that B is independent of m in this network.

In the description of the multiplier below I refer solely to the information being accrued by the representative member. However, there is also information both emanating from and being passed on by the representative member. It is important to remember that both the members and the network are symmetric, so what holds for one member holds for all. The members all input specific knowledge, pass knowledge on and accrue knowledge additional to their specific knowledge. Assume that the network is structured in the most efficient way, i.e., given that all members can make B direct links, they link up in such a way that the lengths of the path between any member and all the other members is minimized. It is also assumed that nothing can be gained from hearing a piece of information via two different routes and so, given that more information is lost the more people it passes through, we only need to take account of the shortest routes. Hence, the gross information network multiplier is given by the following equation:

$$(6) \quad H(B,m,v) = 1 + Bv + B(B-1)v^2 + B(B-1)^2v^3 + B(B-1)^3v^4 + B(B-1)^{s-1}v^s + zv^{s+1}$$

This multiplier is easier to understand term-by-term. The first term again reflects the fact that the representative agent retains her specific knowledge. Once again, this term is eliminated in the net multiplier. The second term states that the representative agent has a direct link with B other agents, lets call them friends, and from each of these she gets a proportion v of their specific knowledge. Moving on to the third term, these B friends have B friends themselves. For each, one of these friends is the representative agent and the other B - 1 are distinct from the representative agent. Hence, the representative agent has B(B - 1) friends of friends from each of whom she gets v^2 of their specific knowledge. The fourth term states that the representative agent gets v^3 of the specific knowledge of her $B(B-1)^2$ friends of friends of friends, or friends three times removed. The fifth term refers to friends four times removed and so on. If the size of the network, m, is infinite, then this series continues indefinitely. However, when the network size is finite and even[7], the series is truncated, as in equation (6). In this case, s is the length of the path along which the knowledge originating from the last 'full' level of friendship, friends s times removed, must flow to get to the representative member. z is the residual number of network members that fall into the next level of friendship, friends s+1 times removed, which is not full ($z < B(B-1)^s$) and for whom the length of path to the representative member is s+1. Mathematically, s and z are given by the following equations:

(7)
$$s = \max \left[s\colon m > 1 + B \sum_{j-1}^{s} (B-1)^{j-1}\right]$$

and

(8)
$$z = m - \left[1 + B \sum_{j=1}^{s} (B-1)^{j-1}\right]$$

where j is the path length. If

(9)
$$m = 1 + B \sum_{j=1}^{s} (B-1)^{j-1}$$

then z is equal to zero and s is the maximum path length in the network. If m does not satisfy Equation (9) then z is positive and the maximum path length is s+1.

Once again the multipliers are positively related to the size of the network, $H_m > 0$. The second order partial derivative of the multiplier with respect m is less well behaved. However, for a sufficiently large, integrated and efficient or community spirited network it holds that $H_{mm} < 0$. There is a positive and convex relationship between the efficiency of, and the degree of community spirit within, the network, i.e., $H_v > 0$ and $H_{vv} > 0$. Finally, the higher the degree of connection of the network the higher the multiplier, $H_B > 0$, and, for

[7] When m is odd one cannot always (it depends on whether Equation (9) holds) refer to symmetry or the representative agent. This is because in such cases not all agents can make the same number of bonds.

a sufficiently large, integrated and efficient or community spirited network, the relationship is approximately linear, $H_{BB} = 0$.

3.3. Cliques and the information multipliers

So far we have looked at symmetric networks where the level of membership has been equal to the size of the population under analysis. It is interesting to consider what happens when the population of agents, rather than all being in the one network, is divided up into sub-groups or cliques. The term 'clique' has been applied to many different structures in social network analysis. All of these structures satisfy the following description: they are 'groups of mutually connected individuals or [...] pockets of high density,' (Scott, J. (1991), page 103.) However, the strict sociometric definition of a clique refers to a sub-group of a population in which every possible pair of agents is directly linked. There are several extensions of this concept including the 'n-clique'. Here, n is the maximum path length between any two members. (So, a clique is a special case of an n-clique, where n = 1.) The network in Section 3.1 is a clique and the one in Section 3.2 is an n-clique, where n equals s or s+1. These sociometric definitions do not, however, encompass one important aspect of the definition of a clique that I gave in Section 1 of this paper; that there are few or no links traversing the bounds of the sub-group joining it with the rest of the population. If this separation is complete, i.e., there are no links between the members of the sub-group and the rest of the population, then my definition of a clique would coincide with the sociometric definition of a 'component' (see Scott, J. (1991), page 104). It is for a population containing such sub-groups that I state the information network multipliers below. However, future work will incorporate the idea that the sub-groups in a population might be linked, at which point the term 'component' will no longer be appropriate. I have chosen to use the word 'clique' for this reason and because in its general usage it suggests both the high density of interaction within the sub-group and the relative isolation of the sub-group from the rest of the population.

Consider a population of N agents a proportion, p, of whom share a particular characteristic and the remaining (1-p) of whom share its opposite. Which characteristic an agent possesses determines with whom she networks. So, this population contains two cliques with no weak ties and for the purpose of calculating the network multiplier m equals pN for one clique and (1-p)N for the other. The network multipliers are

$$H(B,pN,v) < H(B,N,v)$$

$$\text{and} \tag{10}$$

$$H(B,(1-p)N,v) < H(B,N,v)$$

The analysis is similar for a population divided into more than two cliques. It is clear that the average information network multiplier for a population divided in this way is less than that for an undivided population. Such populations could be described as having two or more distinct networks or one network containing two or more cliques. In the context of this paper it is purely a matter of choice. However, in anticipation of the time when links between agents in different cliques are introduced into the model, the second description is preferred.

3.4 Network size, network efficiency and the level of community spirit

From the inequalities in (10) above we may conclude that the existence of cliques always reduces the information network multipliers. However, this conclusion is based on the assumption that B, m and v are independent of one another. On the contrary, it is likely that, while B is independent, v and m are inversely related. Many authors, both in economics (See Olson (1965)) and in other social sciences, have suggested that community spirit is greater within small groups. An entrepreneur will be more disposed to share her trade secrets with others if she knows they are not going to spread too far. In a large informal network a recipient of information may have to convince her source that very little will be passed on (low v) before she is told anything at all. Under these circumstances we should write the multipliers as H(B,m,v(m)) and h(B,m,v(m)), where the first order partial derivative of v with respect to m, v_m, is negative. There would then be an optimum size of network such that (assuming the second order conditions for a maximum are met.)

$$H_m = - H_v \, v_m \qquad (11)$$

Consider the case where the optimum size of network is significantly smaller than the size of the total population of firms. Then the information network multipliers are at their maxima for a population separated off into cliques each containing the optimum number of firms.[8] The key point here is that cliques are not necessarily bad.

3.4 Links between agents in different cliques

Returning briefly to the subject of links between agents in different cliques, it is intuitively obvious that such links would enhance the diffusion of knowledge by increasing the information network multipliers. However, there will be a trade off between the number and importance, with respect to the amount of information they carry, of such links traversing the bounds of a clique and the community spirit of that clique.

3.5 The information network multipliers as measures of the 'publicness' of knowledge

The properties of the information network multipliers are such that they act as measures of the 'publicness' of knowledge within an economy. When there is no information network in the economy, knowledge is a private good. In this case the multiplier H(B,m,v(m)) equals

[8] Even though there is now an optimum size of network or clique, the size is still assumed to be exogenously determined and not necessarily optimal.

1, while the net multiplier equals zero. When the information network is perfect, knowledge is a pure public good, i.e., all knowledge is shared by all. In this case the membership of the network equals the population, N, and the multipliers H(B,m,v(m)) and h(B,m,v(m)) equal N and N-1 respectively. In general, an information network exists but is imperfect and the multiplier H(B,m,v(m)) lies in the interval between 1 and N, while $0 < h(B,m,v(m)) < (N - 1)$. It is because the network is not perfect and because agents' relative positions matter, that the content of each agent's final holding of knowledge is different, even though symmetry ensures that they are quantitatively the same. In this model knowledge is non-rival and semi-public and it is because of its semi-public nature that each agent has a different perception of the overall stock.

4. A Simple Model of Economic Growth

It is clear that Equation (2) represents the limiting case of a perfect information network through which all knowledge is shared. Using the information network multipliers, we are now in a position to replace Equation (2) with one that reflects the structure of the information network that exists within the economy and the semi-public nature of knowledge. In this way we can establish the relationship between this structure and the rate of economic growth.

To generalize the model we can either replace Equation (2) with Equation (3) or replace K_i with K_{+i} in Equation (1), the production function, and replace Equation (2) with $K_{+i} = h(B,m,v(m))k_i$. The second option requires a corresponding reinterpretation of the model. Now output is dependent on labour, firm specific knowledge and the additional knowledge that the firm gains through the information network.[9] Thinking about the assumed technology in this way leads us to the question, why is firm specific knowledge different from

[9] Note that with technology represented in this way, if there is no networking and no common knowledge there is no production. This does not seem so far fetched when one remembers how long Homo Sapiens has been a social animal.

the other knowledge used in production, i.e., why do we not just have K_i in the production function and why are k_i and K_{+i} combined non-linearly? There are two possible answers to this question: first, the distinguishing feature of firm specific knowledge might be its relevance. The additional information the firm gains through the network sheds light on its specific knowledge, thus augmenting it in a non-linear manner, but it is not productive in the same way as the firm specific knowledge because it is less relevant. If we adopt this argument we need to replace the assumption that the specific knowledge held by each member of a network is of equal value to all members with the assumption that the specific knowledge held by each member is of equal value to all other members, while being of greater value to the original owner. The second possible answer relates to the fact that whereas a firm knows the whole of its package of specific knowledge, it only has a partial view of the other knowledge it gains through the network. Again, partial information of this kind sheds light on the firm's specific knowledge, thus augmenting it in a non-linear manner. Which of these two explanations we accept does not affect the model developed below.

The endogenous growth model presented here is based on the following production function

$$y_i = L_i^{1-a} k_i^a K_{+i}^b \tag{12}$$

where

$$K_{+i} = h(B,m,v(m))k_i \tag{13}$$

For this production function to be consistent with a decentralized equilibrium, firms must treat K_{+i} as exogenous. This they will do if the multiplier H(B,m,v) is exogenous, which has already been assumed, and sufficiently large to make $k_i/K_i = 1/ H(B,m,v)$ negligible. This will be the case if the network is large in terms of membership and sufficiently integrated and efficient.

Equations (12) and (13) may now be used as the foundation for an endogenous growth model that incorporates the concept of social structure through the information network multiplier. For simplicity, assume that there is one unit of labour in each firm and that labour also 'produces' the firm specific knowledge and provides all the entrepreneurial skills. It follows that there are the same number of consumers in the economy as there are firms. The savings rate equals s, so consumption per unit of labour is

$$c_i = (1 - s)\, y_i \tag{14}$$

and

$$\frac{\dot{c}_i}{c_i} = \frac{\dot{y}_i}{y_i} \tag{15}$$

Agents' foregone consumption is spent on accruing specific knowledge. This process of accrual can be thought of in two ways: firms can either be undertaking R and D or using costly weak ties with agents outside the population under analysis to increase their specific knowledge. The second option would be more appropriate in the context of developing countries. In either case, given that this process is costly, only relevant knowledge is accrued in this way. This is in contrast to the knowledge that flows around the exogenously determined symmetric network, that is free and less relevant.

The optimization problem for the representative consumer or unit of labour is

$$\max_{c_i} \int U(c_i) e^{-rt} dt \qquad s.t.\ \dot{k}_i = k_i^{a} K_{*i}^{b} - c_i \tag{16}$$

where $U(c_i)$ is the utility function and r is the rate of time preference or the discount rate if we assume risk neutrality. Let

$$U(c_i) = \log c_i \tag{17}$$

then the Hamiltonian is

$$H_c = \log c_i + \lambda(k_i^a K_{+i}^b - c_i) \tag{18}$$

and the first order conditions are

$$c_i = \frac{1}{\lambda} \tag{19}$$

$$\dot{k}_i = k_i^a K_{+i}^b - c_i \tag{20}$$

and, recalling that K_{+i} is treated as an exogenous variable by the firm

$$\dot{\lambda} = \lambda r - \lambda a k_i^{a-1} K_{+i}^b \tag{21}$$

From Equation (19) we get

$$\frac{\dot{c}_i}{c_i} = -\frac{\dot{\lambda}}{\lambda} \tag{22}$$

Substituting for K_{+i} in Equation (21) using Equation (13) gives

$$\dot{\lambda} = \lambda r - \lambda a k_i^{a+b-1} h(B,m,v(m))^b \tag{23}$$

and bearing in mind that the rate of growth of the economy, g, is equivalent to the rate of growth of the income of the representative consumer

(24) $$g = \frac{\dot{y}_i}{y_i} = \frac{\dot{c}_i}{c_i} = -\frac{\dot{\lambda}}{\lambda} = ak_i^{a+b-1}h(B,m,v(m))^b - r$$

It is clear from Equation (24) that if a+b < 1 growth will slow and then stop when the private marginal productivity of knowledge falls to equal the discount rate, r. If a+b > 1 growth will be explosive. There is only one case in which a steady state exists and that is when a+b = 1. In this case the constant rate of growth is

(25) $$g = ah(B,m,v(m))^b - r$$

Equation (25) states that the rate of growth of an economy is affected by the structure of the information network that exists within that economy and the rate of interest. The accumulation of knowledge is the driving force behind sustained economic growth, but it is the structure of the information network that determines how freely knowledge flows around the economy and so how fast it grows. This complementarity between knowledge and the information network is also evident in the steady state time path for k_i (see Appendix 1 for derivation)

(26) $$k_i(t) = k_i(0)e^{(ah(B,m,v(m))^b - r)t}$$

It is clear that the greater the information network multiplier the greater the firms' desired stock of specific knowledge at any point in time.

Any change in the structure of society and hence in the information network will change the rate of growth. If the degree to which the network is integrated, B, increases then the rate of growth will increase,

(27) $$g_B = ab\ h(B,m,v(m))$$

If something increases v without affecting the membership of the network, again the rate of growth increases,

(28) $$g_v = ab\ h(B,m,v(m))^{b-1}\ h_v > 0$$

ssuming that there are no cliques, so m = N, the effect on the rate of growth of an increase in the population is

(29) $$g_N = ab\ h(B,m,v(m))^{b-1}\ (h_m + H_v v_m)$$

The sign of this effect depends on whether or not h_m is greater than $-h_v v_m$, i.e., whether the increase in the population represents a move towards the optimum because the population was sub-optimal before, or away from the optimum because the population was already excessive. This conclusion is significantly different from the conclusion reached in Romer (1986), where an increase in the level of the population always increases the rate of growth, and in Romer (1990), where a similar conclusion is reached but the relevant population is that of skilled workers.

Finally, consider a population of firms that is split up into cliques with, for convenience, the same number of firms in each. Then, while the total population remains unchanged, something causes a redistribution of the firms in such a way that the number of cliques falls and the membership in each rises. This affects the rate of growth in a similar way to the effect of an increase in the population and yet all that has changed is the structure of society.

5. Welfare and Policy Implications

The standard welfare implication of an endogenous growth model of this type is that the rate of economic growth is sub-optimal from the point of view of society as a whole. This follows from the fact that firms treat K_{+i} as exogenous to their decision making process. They only take into account the private marginal product of their firm specific knowledge and not its social productivity and so the level and rate of accumulation of k_i that they choose in each time period are sub-optimal. The socially optimal growth rate, g*, is

$$g^* = (a + b)\ h(B,m,v(m))^b - r \tag{30}$$

In addition to this standard welfare implication, this model provides welfare and policy implications relating to the structure of the information network (and potentially the structure of society upon which it is based) and its effect on the rate of economic growth. To the extent that a social planner or policy maker can manipulate B, m and v, she should aim to: increase B, the level of integration of the network; increase v, the efficiency of or community spirit within the network, for any given level of membership; and adjust the configuration of cliques within the population in order to bring their memberships closer to the optimum. In the case of the latter this means that if, prior to intervention, the membership level in a representative clique is sub-optimal the policy maker should reduce the number of cliques and increase the membership level in each, whereas in the case of excess membership in each clique she should do the opposite.

6. Examples of Information Networks and Their Role in Economic Growth

The theory outlined above may help to explain the relative success of the Japanese economy. In many respects Japanese firms represent highly integrated and efficient cliques. In Japan, the workplace has always been an important arena for the formation of social networks and, until recently, internal labour markets have ensured little movement of employees between firms. The long term and multifaceted relationships between firms and employees ensure a high degree of community spirit and that the cliques operate efficiently, while the lack of movement between firms reduces the number of network links traversing the borders between firms. The Japanese trading companies and trade associations provide the network that links the firms together (See Johnston and Lawrence (1988).) This second network involves only a few high ranking individuals in each firm, leaving the firms' internal networks to operate without hindrance. It coordinates the firms' activities by informing them of each others needs and of the developments in world markets. Government policy has often worked to strengthen the structure of these networks as well as to promote the constant seeking of new knowledge either through domestic R and D or through the exploitation of links with the rest of the world.

The theory also suggests how certain institutions may have played a critical role in the rapid economic growth of Europe in the eighteenth and nineteenth centuries. There were the urban coffee houses, renowned as meeting places where ideas were both developed and exchanged, where people from all walks of life including academics and entrepreneurs met primarily for social reasons but never-the-less gained economically. Another common institution of that time was the guild. In 'Institutions, Institutional Change and Economic Performance,' North (1990) identifies the guilds as instrumental in the development of mechanisms for the enforcement of contracts (see pg. 127). This was undoubtedly an essential step in the development of institutions conducive to the exploitation of increasing returns due to specialization (see Romer 1987) and hence to growth. However, the model presented above suggests that the guilds were instrumental in another way. They facilitated the building of networks through which information about new technologies, new markets, new contract designs and methods of enforcement, could travel efficiently around the relevant industries.

In both the guilds of eighteenth and nineteenth century Europe and modern Japanese firms there are mechanisms in place to exclude non-members from at least some of the information flowing through the network. In other words, in both cases the level of membership of the networks, m, is controlled, in the first case through the apprentice system and by an extensive set of rules and norms and in the second case by employment contracts that last a lifetime. However, control does not necessarily imply that m is endogenous to the process of accruing information. Other factors relating to the market and production technology are likely to be of greater importance in the choice of m. The networks that centred around the coffee houses contained no mechanisms for controlling membership size.

How can this theory help explain the poor performance of the African economies? First, it might be that v is low in these economies. It seems unlikely that this would follow from a lack of community spirit, but the efficiency of the networks may be negatively affected by the generally low geographical density of businesses and the poor quality of the communication and transportation infrastructures. These and other factors such as the relatively low level of specialization may also have a negative effect on the degree of connection, B, the likelihood of linkages existing between different cliques, and might also suppress the size of cliques to below their optimum.[10] Also, referring back to Abramovitz' third factor of social capability, where there are many cliques formed specifically for the preservation of vested interests, there are likely to be few links between the cliques because agents will be trying to maintain information monopolies. Olson's (1982) vested interests argument and Krueger's (1974) related rent-seeking argument have often been used to explain slow growth in developing countries.

To this characterization of an African economy as having a low level of efficiency with respect to sharing information, a low degree of connection and many, possibly sub-optimally sized, isolated cliques, I now wish to introduce the idea of a modern enclave. This enclave is usually small relative to the economy as a whole and situated in the major urban area of the country, perhaps with well connected satellites elsewhere. For this and other reasons, within the enclave there is likely to be a strong network, i.e., efficiency and the degree of connection are high. Links between the modern enclave and the rest of the economy are unlikely to exist. The rest of the economy has few linkages between its own cliques; there seems little reason why there should be linkages spanning the potentially far greater technological, social and cultural distance between it and the modern enclave. Finally, the modern enclave, unlike the rest of the economy, has links with the rest of the world and so has more new information flowing into its network. This new information will diffuse throughout the modern enclave, but it will rarely reach the rest of the economy. Even if there

[10] If people do not specialize so much they do not have to trade so much and so they potentially have less contact with others. Subsistence farmers are the ultimate example of less specialized producers. Given the high level of risk they face, the networks they are part of are likely to be security enhancing rather than information carrying. They will be very small, highly integrated and isolated (see Granovetter 1982).

are some linkages between the modern enclave and the rest of the economy, the low level of efficiency and degree of connection outside the modern enclave means that the information will not get far. Here, therefore, is an additional explanation of why modern enclaves grow fast, while their host countries remain stagnant. The policy recommendation arising from this analysis is that, if a country is going to encourage foreign investment and the development of new industries it should complement these efforts by developing the information network structure both between the new industries and the rest of the economy and throughout the economy as a whole. There is also a timing issue. The longer a modern enclave is allowed to develop in isolation, the larger the technological distance between the enclave and the rest of the economy becomes and the harder it is to develop useful, self perpetuating links.

In her paper 'Substituting for the State,' Brautigam (1993) presented an explanation of why a group of ethnically distinct entrepreneurs situated in the township of Nnewi in the east of Nigeria experienced a period of considerable prosperity between 1983 and 1991, while there was near stagnation in the rest of the Nigerian economy. Her explanation highlighted the importance of the network of relationships between and the institutions supported by the Nnewi entrepreneurs as well as their relationships with entrepreneurs in other countries. This area of Nigeria has been densely populated for many decades and, due to the consequent scarcity of land, many people have been specialized in their economic activity, especially as traders, for some time. The entrepreneurs that Brautigam studied started in the transportation sector, moving later into the importation of spare auto-parts and latterly into production. This history explains how the observed highly integrated and efficient informal information network and the valuable relationships with producers in other countries came into being. In this case we are not looking at a modern enclave, but the story told in the last paragraph never-the-less fits the facts presented in Brautigam's paper very well.

7. The Link Between the Literature on Social Learning and the Model in This Paper

The social learning literature focuses on the observed effects of information collected in a social context on certain decisions taken by agents. In this paper I have formalized what is meant by social context, making it and its affect on growth the subject of the analysis. In the paper, 'Social Learning: An Application to Kenyan Agriculture,' Burger, Collier and Gunning, look at the relative importance of different factors influencing the decisions of small holders in rural Kenya. They found that female household heads were only influenced by the intentions, decisions and successes of other female household heads, while male household heads were only influenced by the intentions, decisions and successes of other male household heads.

These findings strongly support the hypothesis that within the network that characterizes rural villages in Kenya there are two cliques defined along gender lines and that, when it comes to making decisions about agricultural production, there are no effective (for the purpose of conveying information) links between the two cliques. This raises an interesting point concerning the relationship between the structure of information networks and the structure of social networks. Socially there must be some links between the two cliques. It appears however that these were not used for the conveyance of the information that was of interest to the researchers. There are two explanations of why this is so. First, although unobserved factors that make it impractical for household heads of different gender to make the same decisions were controlled for in the analysis, there would have been no way of controlling for the consequence of the genders perceiving themselves as different. It might be that when compiling information prior to making a decision the household heads retain only the information they collect from people like themselves, i.e., their own gender, and discard the information they have from others. If this is the case, even if knowledge is being shared we are unaware of it, because we only observe the consequences. Secondly, the knowledge might not actually get shared because of some other non-economic forces; perhaps it is taboo for men and women to talk business. The important point here is that the social network represents an 'upper bound' on the information network, which may be far less dense and contain far more cliques. Only after an empirical study of the underlying structure of the social and information networks and of the way they work would we be able to establish the true nature of the gender isolation that is apparent in the Burger, Collier and Gunning's analysis.

8. The Exogeneity of the Information Network

Before drawing my final conclusions, I wish to look more closely at the assumed exogeneity of the structure of information networks. To endogenize the structure of the network is the obvious next step in this line of inquiry. It is interesting to look at the parameters that describe the structure and workings of the information network in turn. That the membership of a network is treated as exogenous by the representative member seems entirely plausible. However, from the point of view of the network as a whole, membership may be a choice variable (recall the Japanese firms and the guilds of Europe.) This issue is closely related to that of excludability in the theory of club goods. The membership of a network may be exogenous and non-excludable, for example the network of casual social links that spreads world wide; it may be exogenous and excludable, as in the case of highly integrated ethnic groups such as the one Brautigam studied; it may be endogenous and excludable, as for formal societies. If the excludability is to relate to the information shared, then the group or formal society must have devices (rules or customs) in place that limit the freedom of individual members to share information with non-members.

Moving to v, the proportion of the knowledge held by a member of a network that she is prepared or able to pass on to others, in the model this variable is assumed to be dependent on membership alone. However, in the introduction the notion of community spirit was suggested as an influencing factor and in the last section I suggested that geographic factors and infrastructure may affect its value. The level of infrastructure is in part a choice variable. Consider for example, installing a telephone. By doing so an entrepreneur would be able to communicate more frequently and efficiently with friends and colleagues with whom she habitually shares information. Moving away from the concept of efficiency, consider the role of the norm of reciprocity in informal networks. Where this norm holds, if an agent increases the proportion of knowledge she shares with other members, ceteris paribus, she will get more in return.[11] Assuming that all one-to-one exchanges of knowledge are reciprocal, v is a choice variable for each pair of agents, determined perhaps by some sort of bargaining process. (With symmetric agents, they will both want the same v and no bargaining would be required.) Any single pair of agents will only take account of the private marginal productivity of the mutually agreed v that relates to their one-to-one interaction. They will take the v's decided by all other pairs of agents as given. But any single pair of agents' choice of v affects the information network multipliers of all the other members of the network, for if they bilaterally increase v, more of each of their packages of specific information are released into the network and less of other's specific information is lost as they pass it between them. This means that v's social marginal productivity is greater than its private marginal productivity. In this sense v is very similar to specific knowledge.

The number of other members with whom a particular member exchanges information, B, is most likely of all the parameters to be endogenous. The link between increasing the number of contacts an entrepreneur has and the amount of information she has access to is clear and B is essentially up to the individual unlike v and m. What this variable has in common with v, however, is the divergence between its private and social marginal product. When a particular member increases the number of other members with whom she exchanges information directly, she reduces the length of the path some bits of knowledge have to travel to some other members and so reduces the amount lost. If one were to consider endogenizing B and v, there is another characteristic of networks that should be taken into account. In the words of Powell (1990), 'You trust best information that comes from someone you know well.' In other words information networks take time to build. An agent cannot increase B

[11] See Powell (1990) for a discussion of the role of this norm in networks.

overnight and v is likely to increase with time.[12] In this context Granovetter's (1985) description of social networks as 'social capital' seems most apt and ties in very neatly with Maurice Scott's approach to economic growth. There is obviously considerable scope for future work in this field.

It is likely that even if we were to endogenize B and v, given the divergence between their private and social marginal productivity, an endogenous growth effect would still exist. The main difference would be that instead of a simple, easily understood model we would have a complex and possibly intractable one.

9. Conclusions

The model presented in this paper suggests that the structure of the networks of interpersonal relationships that exist within an economy is a determinant of the rate of growth of that economy. In the model, this structure is assumed to be exogenously determined. In other words, it is assumed that when agents are building their networks of interpersonal relationships they are not concerned with the effect these networks have on the amount of information that is available to them. Within the context of this simple growth model it is not possible to relax this assumption and still derive a steady state growth rate. There is significant scope for future work in this area.

The primary innovation in this paper relates to how the structure of society has been expressed mathematically. It has been done in a way that could be used to establish the effect of societal structure on many economic outcomes and to forge a link between mathematical sociology and economics.

[12] Many authors writing about social network have looked at how they evolve. The concepts of reciprocity, indebtedness and adaptation are all central to these discussions. For an example of this see Johanson and Mattsson (1987).)

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Appendix 1: Solving the model for the steady state time path for firm specific knowledge

First, recall the production function, Equation (12)

$$y_i = L_i^{1-a} k_i^a K_{+i}^b$$

Differentiating this function with respect to time, using Equation (13) to substitute out for K_{+i} and taking into account the fact that in the steady state a + b = 1, we get

$$\text{(A1)} \qquad \frac{\dot{y}_i}{y_i} = \frac{\dot{k}_i}{k_i}$$

then, from Equation (25), in a decentralized equilibrium

$$\text{(A2)} \qquad \dot{k}_i = k_i(ah(B,m,v(m))^b - r)$$

Equation A2 can be solved to give the steady state time path for k_i

$$\text{(A3)} \qquad k_i(t) = k_i(0)e^{(ah(B,m,v(m))^b - r)t}$$

Differentiating with respect to the net information network multiplier yields

$$\text{(A4)} \qquad \frac{dk_i(t)}{dh} = k_i(0)abt\ h(B,m,v(m))^{b-1} e^{(ah(B,m,v(m))^b - r)t} > 0$$