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The Economics of Information and Knowledge

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Introduction

Optimism Versus Realism

We live in an imperfect world and that imperfection is mirrored in our own fallibility. We can never know all that we might know, and we are hard put to sift the relevant knowledge from the information and misinformation that is already pressing upon us. We may make poor decisions on the basis of what we know, we often fail to communicate our knowledge to others, and we may misrepresent our knowledge or lack of it when dealing with others. All of this affects economic transactions and other social interactions as well as the work of enterprises and other organizations.

Economists have often assumed away these fallibilities in their models, as physicists might assume away the effects of friction. But we now understand that economics without human fallibility is like Othello without Iago. If all the characters in Shakespeare's Othello knew what there was to know and communicated truthfully to others, it would have been a simple story yielding little insight into the real world-like some economic models. While the consequences of being "all too human" can sometimes be tragic, our goal is not pessimism but realism. Economic policy advice extracted from realistic models is likely to be far more valuable than advice divined from elegant but Panglossian models of perfect information, unbounded rationality, and truthful behaviour.

The idealism springing from human potential must be tempered by the realism harvested from human fallibility. Within the last few centuries, humanity has developed the knowledge to systematically produce scientific and technological knowledge. This knowledge revolution rivals in importance the discovery of the knowledge to systematically raise agricultural crops, a discovery that launched humanity onto a new path many millennia ago. Today this knowledge revolution is being accelerated by the revolution in the means of processing and communicating information, the ICT and now the AI revolution. But just as human physical activity is beginning to press against the limitation of the natural environment, so these revolutions in knowledge and information are highlighting even more clearly the aforementioned limitations of human intellectual and cognitive powers. The acceleration in the quantity and complexity of information is forcing policy-makers in the developing world (as well as the

developed world) to play closer attention to knowledge dynamics. Between the pincer-like movements of optimism and realism, we will try to capture useful policy advice about the information and knowledge issues of development.

These two broad themes of informational optimism and realism can be represented in simple diagrams. We are always concerned with some human organization or system where knowledge or information is

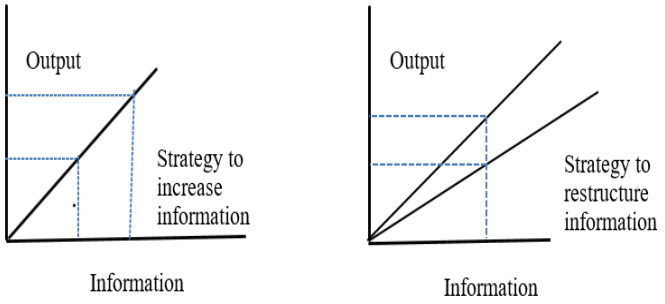

Figure 1: The Two Strategies

an "input" used to produce some "output" or desirable outcome. A rising curve indicates that more input leads to more output. We then see that there are two information-related ways to increase the level of output: increase the level of information in the system to increase output ("move along the curve"), or restructure the information-output relationship to obtain more of the desired output at each level of informational input ("shift the curve"). This is illustrated in Figure 1.

Adam Smith and the Realism of Self-Interest

In Adam Smith's time, two lines of thought could be discerned.[1]

> One of these lines stressed the role of social welfare of man's instinctive capacity for disinterested benevolence, and came to be caJled the "sentimental" school. The other stressed the incidental harmony between behaviour engaged in from calculated self-interest and the public good, and acquired the label of the "selfish" school, where "selfish" meant, however, merely calculated self-interest (Viner 1972, 68), [11].

Smith's first book, *The Theory of Moral Sentiments,* published in 1759 could be seen as a contribution to the sentimental school. Smith amply illustrates that not all social, political, and economic activities are based on calculated self-interest. Within small social distances (e.g., within the circles of family, friends, and associates) or for short spans of time (e.g., collective efforts of public spiritedness), people can and do base their behavior on disinterested benevolence, goodwill, fellow-feeling, and social trust. But if institutions were designed for a broader and more enduring society on the assumption of these angelic virtues, those institutions would only survive in a society of angels. They would not be robust in a human society.[2]

Yet Smith saw that society could be well-ordered without being based on benevolence.

> Society may subsist among different men, as among different merchants, from a sense of its utility, without any mutual love or affection; and though no man in it should owe any obligation, or be bound in gratitude to any other, it may still be upheld by a mercenary exchange of good offices according to an agreed valuation (Smith 1969, 124), [8].

The development of that theory awaited Smith's 1776 masterpiece, *The Wealth of Nation*s, where the shift from the "sentimental" to the "selfish" school was signaled by the famous observation: "It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own self interest." This work laid the foundation for the underlying realism of an economic theory based on the postulate of calculated self-interest in a society where one cannot assume "mutual love or affection" [9].

In terms of the broad delineation of two classes of knowledge strategies, the move towards realism (from benevolence to self-interest as the operating assumption) is a restructuring strategy that better incentivizes the decentralized economic agents to productively use their existing knowledge—and to be led thereby "as if by an invisible hand" to further the interests of others. In our own time, this broad restructuring theme is being realized in the historic transformation from communist planning systems to marketoriented societies.

All modem economics stems from Smith. but there are four strands that are most relevant to our knowledge and information theme:

- The Austrian knowledge economics school repre-

sented by Friedrich Hayek and Joseph Schumpeter (and by Karl Popper in philosophy),[3]
- The modem economics of information[4] stemming from the work of Joseph Stiglitz, George Akerlof, and Michael Spence,
- The institutional or evolutionary economics of technical knowledge pioneered by Thorstein Veblen, Kenneth Boulding, Michael Polanyi, Edith Penrose, Richard Nelson together with Sidney Winter, Nathan Rosenberg, Christopher Freeman among many others, and
- The emerging field of studying self-reinforcing or increasing-returns processes which are often related to information and knowledge where pioneering work was done by Allyn Young, Gunnar Myrdal, Albert O. Kirschman, Jane Jacobs, Nicholas Kaldor, and Kenneth Arrow with more recent contributions by Paul David, Paul Romer, Robert E. Lucas, Douglass North, Paul Krugman, Brian Arthur, Robert Putnam, and a host of others.

Austrian Knowledge Economics

The work of Friedrich Hayek in the Austrian school has centered around questions of knowledge beginning with his seminal 1936 essay *Economics and Knowledge*.[5] Hayek's work on knowledge evolved in the debate principally with Oscar Lange over the economic feasibility of socialism [2]. The debate might be posed using the "centralization paradox." Suppose there is some decentralized organization involving a number of economic agents. It might be argued that a centralized organization of the agents might always do the same or better since it could command the units to mimic the decentralized arrangement in addition to implementing other policies to resolve extemality and coordination problems. In particular, "market socialists" argued that a socialist regime could at least simulate the market mechanism, and perhaps improve upon the market outcome.

Austrian "knowledge economics" was fashioned in the heat of this debate. Hayek saw the requisite knowledge about beliefs, preferences, technology, and local conditions as being dispersed between the economic agents. In addition to being localized, the knowledge was partly tacit.[6] This knowledge would be used by the agents if they were acting in their own behalf in a decentralized and competitive market process. The separate agents would perform many local experiments (which might "wastefully" duplicate one another) to discover new knowledge. Prices would evolve to reflect the relative scarcity of resources and to align subjective expectations with the factual state of affairs. In sum, the "view of the market as a competitive-entrepreneurial process for the discovery and coordination of knowledge, has become a central tenet of Austrian thought."[7]

Centralized mechanisms for gathering, processing, and transmitting this information would deteriorate as the informational messages grow more complex.[8] The problems would be compounded by the difficulties of eliciting and transmitting tacit knowledge. Centralized attempts to reduce "wasteful" duplication of experiments would ultimately stifle innovation. Centralized structures might work only for relatively short spans of historical time (e.g., a war effort) to produce simple and standardized products where neither quality nor innovation (not to mention the virtues of liberty, participation, and local ownership) were at a premium-a prediction that does not seem to be falsified by Soviet economic experience. Attempts to "command" decentralized behavior face severe motivational and principal-agent problems (see below), and lack the credible commitment that the "decentralized" decisions will be respected and sustained by the central authorities.

Modern Economics of Information

Differences and Similarities with Austrian Knowledge Economics

Austrian economics has remained largely outside the mathematically-oriented analytical mainstream of modem economic theory—while the economics of information has emerged out of that mainstream to deal with the problems of imperfect information, bounded rationality,[9] and human fallibility. ln spite of these crucial differences in methodology and technique, it is important for our purposes to note that both streams of economic thought share a common reaction against the lack of realism in academic models of idealized static equilibrium (e.g., the modern Arrow-Debreu model) and in idealized models of social utopias.[10]

We will approach the economics of information by giving a series of non-technical examples to illustrate the basic principles and approaches. In particular we need to consider examples of adverse selection problems, moral hazard problems, and agent-principal

problems.

Information Asymmetry

In an informational asymmetry, one party to a potential market transaction much more relevant information that the other party. The possible effect on the market is expressed in the old saying: "I wouldn't want to buy something from someone who is willing to sell it to me."

Suppose someone offers to sell 1% of the money in his wallet, an amount unknown to any buyer. The seller has the right to refuse any offered price. The potential buyers would quickly realize that any price accepted by the seller would exceed the 1% of the wallet money, so the buyer should not take any deal acceptable to the seller. And any deal that would be advantageous to the buyer would be refused by the seller. Thus, the information asymmetry leads to no trades taking place (the absence of the market).[11] A non-trivial example occurs when a corporation tries to raise more equity by offering new shares at the prevailing share price. As the potential buyers realize that the better-informed seller apparently considers the shares to be over-priced (like an "over-priced" offer for 1% of the wallet-money), the share price will fall. The market's reaction might be quite different if the shares had been offered by uninformed small shareholders who only want to diversify their holdings.

Adverse Selection Problems

The seller of a good or service (e.g., a used car or labor services) typically has much more information about the quality of the good or service than the potential buyer. The buyer might only know the average quality offered on the market. If an item is below average (e.g., a "lemon" used car), the seller has an incentive to hide and misrepresent that information. If the item is above average (e.g., a "peach" of a used car), the seller has the incentive to "reveal" that information but the buyer needs grounds to differentiate that message from that of the seller misrepresenting a low quality item. Similar problems arise in insurance markets. A person seeking health insurance or car insurance might have hidden information about health problems or driving problems that is unavailable to the insurance company. In capital markets, the entrepreneur has much better information than the potential funder about the prospects of the capital project to succeed and to pay back the loan or investment.

If price adjusts to account for the low quality items (the "lemons"), the owners of the high quality items will leave the market so that tactic only "adversely selects" the low quality items. If there are finer gradations of quality, the price might continue to fall until only the lowest quality lemons are being sold. What can be done in practical terms to alleviate the problems of adverse selection?

Perhaps the simplest example of adverse selection is Gresham's Law that "Bad money drives out good." Suppose good and shaved ducat coins are both known to be in circulation but that market participants cannot tell the difference. If the sellers of commodities start to count a ducat coin as having say only 95% of its face value, then those who know they have good (unshaved) coins will hold them out of circulation, so the shaved ducats will be "adversely selected" over the good ducats to stay in circulation. Thus, a simple adjustment of relative prices does not resolve the problem.

Since there is an information gap between the two sides of the market, there are two classes of approaches: increase the information available to the information-poor side of the market, or increase the incentives for the information-rich side to signal or reveal its information in a credible manner. These might be called respectively the approaches of improved monitoring and searching, or improved incentives. These two approaches are simply the instances in the context of an information asymmetry of the two broad information strategies outlined above: increase the information in the system, or restructure incentives to better utilize existing but perhaps hidden information.

An example of improved monitoring in the used car market is the common practice of potential buyers to have the car inspected by an independent mechanic. Or a used car buyer might purchase a used car guide from an organization that has already undertaken the search to tell which cars are likely to be lemons. Fearing that a credit card might be a "lemon," a merchant phones a centralized database that monitors which cards are stolen or have exhausted their credit limits. In a similar manner, sellers of health or driver insurance might search databases for information about past health or

driving records. Time without an accident claim is evidence of good driving habits. A loan officer in a bank might undertake a similar "background search" on the loan applicant and apply "due diligence" in investigating the loan application. The information garnered by the improved monitoring and searching allows the information-poor side of the market to structure a better transaction from its point of view.

The Beatles sang about "You Can't Buy Love." The Beatles could as well sung about reputation. Any scheme which allowed "reputation" to be bought (rather than earned) would soon be vulnerable to low-quality sellers buying a "reputation" and destroying its value for the high-quality sellers as well. When markets are failing due to quality information problems,[12] public or private associations can set up quality certification "stamps of approval." Earning a stamp of approval is one way of earning a reputation-if the stamp itself has a reputation. But the process would break down if corrupted by allowing the "stamps" to be purchased.

The other approach is to restructure the incentives for the information-rich side to credibly reveal its information. The seller of a good car might signal quality by offering a warranty. High-risk and low-risk applicants for health or driving insurance might be separated by well-designed contracts with differing combinations of premiums and benefits to better match the contracts to the risk categories. The loan applicant might put up personal assets as colJateral. One form of collateral is reputation. A used car dealer would seek to establish a credible reputation for honest dealing. The Grameen Bank microfinance program in effect uses a person's social reputation as collateral.[13] Moreover, since the peer group is jointly liable to pay back the loan, they will provide lower cost monitoring of performance than could a loan officer. In general, it is the adverse selection problem that leads lenders to use improved monitoring and incentives to intelligently ration credit instead of just raising the interest rate until the market cleared.

Moral Hazard Problems

"Moral hazard" is the tendency for the insured to exercise less care. In the examples of adverse selection in insurance markets, it was important that the riskiness of an applicant is "given" and is not a matter of choice. If the riskiness can be changed by the applicant "taking care" (e.g., stopping smoking or putting on seat belts), then it is a potential moral hazard problem. If the insurance company could easily monitor and enforce the insured's precautionary behavior, then taking proper care would be written into the insurance contract. Moral hazard is more problematic when the information about which actions are taken is hidden from the other side of the transaction.

Here again, we expect two approaches: improved monitoring and improved incentives.[14] The insurance company might inspect a fire-insured building to check the fire alarms and sprinkler systems. Insurers might consult databases for evidence of past negligence. From the incentives viewpoint, moral hazard arises because "excessive" insurance allows individuals to escape bearing the full costs of their careless actions. Insurance benefits need to be limited (e.g., through co-payments and deductibles) so that the insured party will "pay the price" unless care is taken. Moral hazard problems can be particularly important in the financial sector. Regulators of banks and other financial institutions use both monitoring and incentive approaches so that deposit insurance and other state guarantees do not lead to moral hazard. Implicit guarantees and explicit bailouts for financially distressed companies, financial institutions, and even countries can lead to moral hazard unless measures are taken for them to "pay the price" of negligence. The possibility of bankrupting a corporation serves as a type of "insurance" for the shareholders against large losses-which could lead to less care in taking risks. Hence banks may "pierce the veil" of small closely-held corporations and ask the major shareholder to personally co-sign for the loan to provide the incentive to exercise care.

Principal-Agent Problems

In the principal-agent relationship, the principal hires the agent to carry out certain activities in the interests of the principal. The employer-employee relation is a principal-agent relation, as is the relation between the shareholders of a corporation and the management. Government officials are agents exercising authority delegated from the citizens as principals. The problem is that the principals do not have full information about the activities of the agents, so the agents might opportunistically tend to pursue their own self-interests.

One way to resolve the problem is by eliminating

the relationship through unification of principal and agent-such as through management ownership (for the shareholder-manager relation) or worker ownership (for the employer-employee relationship). Without unification, there are the usual two basic approaches: the information-poor side of the relation (principal) can improve monitoring, or the incentives can be restructured for the information-rich agents. For better monitoring, shareholders might insist on independent members of the board of directors and on improved internal accounting and reporting procedures. Public officials might be required to reveal their financial activities. A free press can serve as the best continuing monitor. For better incentives, there is a wide variety of performance-related compensation packages which might motivate the agents to choose unmonitored actions more in line with the principal's interests. Techniques to mitigate principal-agent problems in private business have also been adapted to public government.

Summary of the Two Approaches

In the informational asymmetries of the adverse selection, moral hazard, and principal-agent problems, there is an information-poor and an information-rich side of the relationship. Thus there are two strategies to address the problem: improve the monitoring or searching so the information-poor side has more information and can act accordingly, or restructure the incentives for the information-rich side of the relation to reveal or otherwise use the hidden information in a less opportunistic manner. These approaches are summarized in the following Table 1.

Information Gap	Monitoring Approach: Increase information state	Incentives Approach: Restructure incentives state
Adverse Selection Problem (e.g., lemon-peach market)	Car inspection. Used car guidebooks. Checking databases on credit applicants.	Seller warranty to signal quality. Use of reputation or other collateral.
Moral Hazard	Better monitoring and use of centralized databases to learn of past negligence	Deductibles and co-payments. Risk sharing to pay the price of negligence.
Principal-Agent Relation	Better monitoring by board. Improved management information system.	Performance-related compensation.

Summary of two approaches to handling information gaps

There are other possibilities. Unifying the two sides (e.g., self-insurance or self-employment) would resolve the informational asymmetry (while perhaps leaving other risk allocation problems). It is also possible for the government to use its powers of coercion to partially address these problems, e.g., mandatory automobile or health insurance, mandatory precautions such as seat belts, food and drug regulations, and consumer rights (such as lemon laws). We have chosen the problems of information asymmetry (adverse selection, moral hazard, and principal-agent problems) to illustrate the modem economics of information.

Institutional Economics of Technical Knowledge

Institutional economics takes a broad and non-analytical view of knowledge. Institutions as "habits of thought." As knowledge accumulates, the habits of thought change, and that transforms industry, economy, society, and culture-all of which affects, in tum, the advance of knowledge in a process of cumulative and endogenous causation [10].

It has long been a commonplace to recognize the importance of knowledge, particularly technological knowledge, in production. Instead of seeing knowledge as another factor of production alongside the traditional trinity of land, labor, and capital, Kenneth Boulding (1978) proposed the taxonomy of knowledge (know-how) together with matter and energy (or following Einstein, matter-energy). ln short, it is the stuff of the mind and the stuff of the world that come together to produce the human world of artifacts. This taxonomy avoids the double-counting of considering knowledge as fourth factor of production along side the embodied knowledge in labor

and capital. Yet Boulding realized that knowledge has underlying characteristics quite different from the traditional "factors of production." For instance, one unit suffices; Einstein only had to discover the special theory of relativity once.[15] Moreover, the possession of knowledge is "non-rivalrous" between people; Einstein did not "lose" the theory when he imparted it to the world.

Perhaps the earliest explicit recognition of the non-rivalrous nature of knowledge was by Augustine of Hippo.

> The words I am uttering penetrate your senses, so that every hearer holds them, yet withholds them from no other. Not held, the words could not inform. Withheld, no other could share them. Though my talk is, admittedly, broken up into words and syllables, yet you do not take in this portion or that, as when picking at your food. All of you hear all of it, though each takes all individually. I have no worry that, by giving all to one, the others are deprived. I hope, instead, that everyone will consume everything; so that, denying no other ear or mind, you take all to yourselves, yet leave all to all others. But for individual failures of memory, everyone who came to hear what I say can take it all off, each on one's separate way" (Augustine quoted in Wills 1999, 145), [12].

These characteristics of knowledge lead to the increasing-returns nature of the many knowledge-related processes considered in the next section.

Not all knowledge that is embodied in people can be explicitly communicated to other people. People know more than they can say or articulate (e.g., knowing how to ride a bicycle). This tacit or personal knowledge is juxtaposed to codified or explicit knowledge that can be more readily transmitted between people. Tacit knowledge can be partly transferred through apprenticeships and other forms of crosstraining, or it might be codified and then transferred. The contrast between tacit and explicit knowledge was first emphasized by Michael Polanyi [16] and was to play an important role in the institutional economics of technical knowledge [5].

Edit Penrose noted in her theory of the firm that "Economists have, of course, always recognized the dominant role that increasing knowledge plays in the economic process but have, for the most part, found the whole subject of knowledge too slippery to handle." (1959, 77) For her, the firm was an everchanging repository of knowledge. It is not resources but their services which are actuaUy used in production, and the use of those services was determined by the accumulated firm-specific knowledge. Firm-specific knowledge, particularly the tacit variety, has a notable effect on organizational form, e g., personnel and training policies.

Richard Nelson considers reasons for the different treatment of individuals and organizations in neoclassical economics and in institutional/evolutionary economics.

> First, as a 'starring place' for theorizing, neoclassical economists assume that individuals and organizations have an accurate understanding of the circumstances they are in, and the options they face, and have the cognitive capabilities and the opportunity to assess the best action. Institutional and evolutionary economists, in contrast, stress the limits of human cognitive capabilities relative to real-life decision problems they face, and the real time involved in thinking through any problem (Nelson 1994, 249), [3].

This vision of institutional-evolutionary economics is clearly in line with the theme of informational realism described above.

Nelson and Winter (1982) give an analysis of knowledge in the firm that is quite relevant to the concerns about technology transfer to developing countries. Much of the know-how embodied in technical routines has the form of non-codified tacit knowledge that cannot be directly transferred. Much of the know-how is also embedded in the manner of interpersonal interactions of teams that might function quite differently in other cultures. Western development institutions therefore should not implicitly adopt a model of technology transfer such as "buying a machine, reading the instructions manual, and then turning on and using the machine." Imitating and borrowing involves reinventing at least the tacit and localized components of the routines to fit the new conditions. That implies a very active role for the individuals and organizations

adopting the technologies, not the passive role of an aid recipient.

There are other implications for organizational structure. Within the firm, the transfer of localized tacit knowledge takes place mainly through horizontal apprentice-like relations, not vertical training from managers to workers. Moreover, the information transmitted upwards in a hierarchy to inform decisions is explicit codified information, so decisions are made in a hierarchical structure without lower level uncodified tacit knowledge. Better decisions might be made lower in the hierarchy closer to the source of the knowledge. When these local decisions require informational inputs from various different job categories, it is best for the decision-makers to have rotated through those job categories to have acquired their tacit components.

These arguments for fuzzy job boundaries and job rotation cut against the traditional arguments for specialization and division of labor.[17]

The Economics of Increasing Returns and Other Self-Reinforcing Processes

Introduction

We use this category to pull together work on a number of knowledge-related self-reinforcing phenomena. It is a large tent that includes the informal work on vicious and virtuous circles (cumulative circular causation) that runs through the literature of development economics[18] as well as economic theories that feature increasing-returns processes, from the early work of Young and Kaldor through the recent work on strategic complementarity, the new growth theory emphasizing endogenous knowledge-related self-amplifying processes, and network economics.[19] The work in this area substantially overlaps with the institutional and evolutionary economics of technical knowledge considered above; we have used the explicit emphasis on self-reinforcing processes to delimit the work now being considered.

Non-Rivalrousness of Knowledge

Knowledge and information have unusual characteristics. There is an intrinsic information asymmetry in any market transaction to buy information itself since if you know what you are buying, then you already have the information. Perhaps the most important attribute that lends itself to self-reinforcing processes is the non-rivalrousness of knowledge illustrated by Thomas Jefferson's metaphor that one person can light a candle from another without diminishing the first person's candle. One person's "consumption" of knowledge does not rival another person's. Yet it is possible to exclude knowledge from another person by keeping it private. But once knowledge is made public, it can spread in network fashion and cease to effectively have the property of excludability. Pure "public goods" like the national defense or public health measures against infectious diseases are both non-rivalrous and non-excludable so knowledge and information are partial public goods.

It is useful to conceptually differentiate the pure non-rivalrousness of knowledge from the low cost of dissemination. The information revolution results in part of the great strides made in modem technology in reducing the costs of processing and disseminating infonnation. But any material embodiment or encoding of information is still strictly speaking rivalrous. As an overdue notice from a library attests, two people in different places cannot use the same book at the same time. As the waiting time to download from the Internet attests, electronic packets on telephone networks are still rivalrous and can lead to congestion effects. It is only immaterial ("disembodied") knowledge, information, ideas, concepts, functions and other abstract objects of thought that are purely non-rivalrous. Philosophers have long struggled with the best way to talk about the objects of thought that are "in the mind" (e.g., the abstract objects of mathematics such as numbers and geometric figures) since, by assumption, they do not exist as material objects.[20] The number thirteen is represented by the numeral 13 written on this page and describes the number of characters in the English word "non-rivalrous" but the number itself is not identified with any material embodiment. It is the number as an abstract concept that can be shared in a purely non-rivalrous way. We can all use the number thirteen without diminishing each other's or anyone else's use of the number. Disembodied knowledge is non-rivalrousness; it is the process of embodying knowledge in people (learning) and things (application) that is costly in time and resources.

When non-rivalrousness is understood in terms of the mental or mtentional content that is "shared" when we communicate and understand one another, then it is seen to be independent of truth and falsity. We can

all share the idea of pigs that fly without there being any truth to the notion. Misinformation is as non-rivalrous as information. The low cost of information transmission allows rumors, true or false, and expectations, founded or unfounded, to rapidly spread and add volatility to many social mechanisms.

Vicious and Virtuous Circles

The falling costs of information transmission coupled with the non-rivalrousness of (disembodied) knowledge and infonnation have accelerated many knowledge-related self-reinforcing social and economic processes. Knowledge-related positive feedback and increasing returns processes are amplified so that they quickly "snow-ball" in a certain direction until eventually meeting some countervailing force. For developing countries, processes of "catching up" or "falling behind" can be respectively accelerated or aggravated (at least in relative terms). These divergence dynamics are sometimes called the "Matthew Principle" after the Biblical reference: "For to every one who has will more be given, and he will have abundance; but from him who has not, even what he has will be taken away." (Matthew 25:29) In the informal literature, self-reinforcing processes are often called "vicious circles"[21] or "virtuous circles" depending on whether the outcome is considered undesirable or desirable.[22] Vicious and virtuous circle models are used in both a dynamic and a static way. For instance, a "vicious circle" might be a dynamic self-reinforcingdownward spiral, or it might be a static low-level equilibrium locked in by a circular pattern of causality requiring a "big push" to break out of the equilibrium. Vicious and virtuous circles can also have positive or negative externality or spillover effects to create similar or opposite circles in the neighborhood. For instance, a virtuous circle of city growth might have a positive "spread effect" in a suburban neighborhood and a negative "backwash effect" in a nearby rural area.[23] The imagery of vicious and virtuous circles is prominent in the literature[24] on social capital and trust. Social capital and trust are "moral resources" that display the self-reinforcing qualities of increasing with use (or decreasing from disuse). Trust leads to more trust, but it also works in reverse.

> Stocks of social capital, such as trust, norms, and networks, tend to be self-reinforcing and cumulative. Virtuous circles result in social equilibrium with high levels of cooperation, trust'" reciprocity, civic engagement, and collective well-being. These traits define the civic community. Conversely, the absence of these traits in the uncivic community is also selfreinforcing. Defection, distrust, shirking, exploitation, isolation, disorder, and stagnation intensify one another in a suffocating miasma of vicious circles. This argument suggests that there may be at least two broad equilibria toward which all societies that face problems of collective action (that is, all societies) tend to evolve and which, once attained, tend to be self-reinforcing" (Putnam 1993, 177), [6].

Distrust can remove the opportunity to build trust and can lead to self-fulfilling distrustful behavior on the part of others.

Network Economics and Other Knowledge-Related Increasing Returns Processes

Adam Smith's account in *The Wealth of Nations* of the mutual reinforcement between the specialization of labor and the extent of the market was an early account of a knowledge-related increasing returns process. There has been a recent revival of interest in such processes in the literature on strategic complementarity and endogenous growth.[25]

Network economics provides the strongest source of recent interest in knowledge-related increasing returns processes.[26] These processes tend to restructure markets into "winner-take-all" markets.[27] The increasing returns aspect of network connections is easily seen by considering a network with a connection between every pair of members (e.g., a telephone network). If there are N members, then a new member will add N new links to the system so that the extra benefit of new member will tend to increase with the size of the network (ignoring congestion effects). Each additional member of the "network" of English-speakers, QWERTY users, telephone users, users of some app, fax users, and Windows users adds value to the network (an extemality) in addition to the private benefits and costs of access.[28] The information involved in a certain code is not only transmitted at negligible costs, but the value of using that code increases with its wider and wider adoption. An initial advantage of a product or standard from whatever source will be positively reinforced (while competitors will be neg-

atively reinforced), so that it will tend to expand and "lock in" over the whole network.

The simplest model of an increasing returns process is perhaps Polya's Um. An urn contains red balls and black balls [1]. The probability of randomly drawing a red ball is equal to the number of red balls divided by the total number of red and black balls. Suppose that after a ball is drawn, it is placed back in the urn along with one or more balls of the same color (to "one who has will more be given"). Then the probability of drawing a ball of that color has increased on the next drawing and the probability of drawing the other color has decreased. Then one might also take away an equal number of the other balls to keep the total number constant (so "from him who has not, even what he has will be taken away" until one of the balls "goes broke"). To add more types of balls, it would be best to use numbers rather than colors (so there would be so many 1 balls, 2 balls, and so forth up to N balls). These urn schemes can be modeled on computer spreadsheets. Neighborhood effects can be added taking the probability of drawing an n ball as the average of the number of n-1, n, and n+ 1 balls divided by the total number of balls (where the N balls are taken as "next door" to the 1 balls). In such a circle or ring of locations, clusters or cities will quickly emerge untjl finally only one cluster or city locks in and dominates.

Concluding Remarks

The social and economic dynamics of knowledge-driven processes are quite different from materialdriven processes. Our purpose has been to highlight some of these differences. In the bigger picture, the main knowledge-driven process is that of science and technology. As noted in the introduction, during the last few centuries, the discovery of scientific and technological knowledge has taken off from a blind and fortuitous process to become a deliberate self-reinforcing process that can be one of humanity's most promising virtuous circles.

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1. See Hirschman (1977) for a related treatment of these themes.
2. This theme is well illustrated by the trajectory from the idealism of socialist thought in the nineteenth century to the tragedies of communism in the twentieth century.
3. See Hayek 1948 or Caldwell 1997, Schumpeter 1962, or Popper 1962.
4. For expositions and Surveys, see Stiglitz 1994. Akerlof 1984, Laffont 1989, Milgrom and Roberts 1992, Hirshleifer and Riley 1992, Campbell 1995, or Mahlo 1997.
5. Reprinted in Hayek 1948. See (Caldwell I997, 865).
6. See Polanyi l 962) and the section below on institutional economics.
7. Caldwell 1997, 1866. See Kinner 1973 and Sowell 1980 for recent developments of these knowledge-related themes within the Austrian tradition.
8. This is illustrated by the children's game of transmitting a piece of information or a story around a circle of children. A simple message like "7" might survive the journey, but complex information tends to be substantially distorted by the process.
9. Sec Simon 1982.
10. For instance, Stiglitz also emphasizes the importance of informational limitations in making the case against centralization. “The existence and pervasiveness of externalities would- in the presence of unlimited ability of a centralized authority to gather, process. and disseminate information-provide a strong argument for centralization. But the ability of any centralized authority to gather, process, and disseminate information is limited. These limitations form the basis of the argument for decentralization.” (Stiglitz 1994, 156)
11. It is sometimes thought that market failures due to informational asymmetries can be resolved by having "complete" contracts- the latter however being unfeasible due to transactions and enforcement costs. But even with zero transactions and enforcement costs, this example is a zero-sum transaction of money so no set of contractual conditions will allow both parties to gain.
12. See Klitgaard 1991.
13. See Hoff et al. 1993 for economic analyses of peer group lending arrangements.
14. One way to eliminate moral hazard is self-insurance since the insurer and insured party would then be unified. But that would sacrifice the gains from pooling independent risks so we will assume that the insurer and insured party remain distinct.
15. This is the insight contained in the joke schema: "Why didn't company X translate its program into the language of country Y? Because they would only sell one copy"
16. See also Michael Oakeshott 1991.
17. See also Stinchcombe 1990.
18. See for example Gunnar Myrdal 1957, Albert O. Hirschman 1958, Jane Jacobs 1969, and Robert Putnam 1993.
19. See for example Paul David 1985, Paul Romer 1986, Robert E. Lucas 1988, Paul Krugman 1991, and Brian Arthur 1988, 1989, 1990.
20. See Searle 1983 for a philosophical treatment of the "shared" intentional content that seems to be the root of the economists' notion of non-rivalrousness.
21. Gunnar Myrdal (1944, 1957, and 1968) did the most to popularize the notion of the vicious circle in the economic development literature particularly to account for persistent and increasing national and international inequality. Jay Forrester's work on system dynamics applied positive and negative feedback loops to industrial models (1961]) and Peter Senge (1990) has popularized

these tools in the management literature.

22. It might be noted that there is nothing "positive" in the positive feedback of a vicious circle. In a positive feedback loop, The deviation of a variable from a norm is amplified (rather than damped as in a negative feedback loop) so that the deviation is reinforced and the variable "snow-balls" away from the norm.
23. See Hirschman 1958.
24. For instance, Putnam 1993 and Gambetta 1988. Sec also Arrow 1974, Fox I 974, and Fukuyama 1995.
25. See Romer 1986, Lucas 1988, North 1990, and Krugman 1991, with early work by Young 1928 and Kaldor 1978.
26. See David 1985, Arthur 1988, 1989, 1990, and Frank and Cook 1995 for treatments of these themes.
27. Frank and Cook 1995 is particularly accessible.
28. The contagion effects of network economics also work on the negative side. Each new member of tile infected "network" not only suffers a private loss but creates the additional social cost of a slight increase in the threat to other members of society.