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Rat-Race Dynamics and Crazy Companies

The Diffusion of Technologies and Social Behavior

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Introduction

How and why do technologies spread when and where they do? What are the implications and consequences for the structure, wealth, and management of human organizations? These expansive questions were the subject of the presentations and discussions of the International Conference on Diffusion of Technologies and Social Behavior, summarized in this paper. The paper is organized under the following headings: empirical regularities; theoretical issues; predictability; time and space; innovation and niche definition; selection dynamics; role of marketing; social aspects; globalization; and applications. While the paper treats some questions for policy in both the public and private sectors, it emphasizes research needs and opportunities in the diffusion field.

The conference represented a convergence and a maturation of studies of diffusion. A great range of disciplines was represented from both the social sciences and the natural sciences. There were geographers, historians, economists, sociologists, psychologists, and political scientists. There were physicists and mathematicians. Along with researchers, there were also practicing engineers and managers. The conference was made more special by the participation of several of the modern pioneers of the exploration of diffusion, including Torsten Hägerstrand, Harold Linstone, Cesare Marchetti, and Robert Pry, people who have facilitated diffusion research over the years and provided many of the ideas on which the conference was built.

The first point to address is why the group came together. The answer is the importance of diffusion as a key process in social and economic change, made powerfully evident by the growing and widespread recognition of regularities of diffusion processes.

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Empirical Regularities

In a sense, the conference, like diffusion research itself, had an empirical origin and a phenomenological orientation. Each discipline, each group of researchers, discovered, somewhat independently, diffusion phenomena. One of the most satisfying aspects of the conference was the presentation of data on newly charted diffusion processes. There were examples of resins and plastics from Vladimir Falzman from the Soviet Union and examples in transport by Veniamin Livshits, also from the Soviet Union. There were two examples on AIDS. There were examples from Oskar Ullman from West Germany in the solar energy area. There were examples on automated banking from the Netherlands (Paul Diederen and Rene Kemp), electronic mail from Sweden (Tomas Åstebro), chain saws from Sweden (Johnny Hjelm), and Catholic saints from Italy (Marchetti). George Modelski presented the spread of democracy as a global diffusion process. The multitude of examples is most important. One of the significant features of the conference was the recognition that there is in fact now a large library of cases of diffusion, perhaps 3000 cases that are well documented and quantified.

One of the major tasks for diffusion research for the next years is the metaanalysis of ensembles of diffusion processes analyzed in the various disciplines. Can one undertake some meaningful taxonomy or classification of the many examples? There might be various criteria, for example, the time constant of diffusion processes (so-called Δts). Other facets to examine might include relationships of clusters of technologies, relationships of levels in the system, and pervasiveness of phenomena, as Roberto Vacca suggested at one point. The job is to look at the patterns of the patterns: to compare countries, to compare industries, and so forth, according to their characteristic forms and configurations of technological innovation and diffusion. The objective would be to identify and eventually explain differences, similarities, and congruences of diffusion processes and their causes.

Whatever discipline one comes from, we all now have a rich empirical library on which to draw. There is, however, a need to make this library and its raw data more accessible.

Theoretical Issues

Although there is excitement and satisfaction with the construction of the empirical base, there is considerable questioning of the adequacy of the theories resting upon the data. In each field, theoretical models have been developed. For example, in economics new mathematical approaches to treat the complex dynamics of diffusion and selection processes and the collective behavior of economic agents were presented by Giovanni Dosi and Gerald Silverberg. They also referred back to earlier contributions in economics by Josef Schumpeter, Edwin Mansfield, and others. In geography, theories and models of Hägerstrand and others were mentioned. Vijay Mahajan presented an overview of diffusion models from the perspective of marketing and management science. New models were shared at the conference as well, by Heinz-Dieter Haustein and in a paper by Ove Granstrand. But one senses that there is considerable dissatisfaction about the theoretical base. We do not feel able to explain the phenomena well. We do not feel we understand mechanisms.

At the same time, there seems to be an acceptance of a vocabulary for talking about the phenomena. The vocabulary is largely derived from the field of biology. There is not too much debate about the usefulness of the biological metaphor. Harvey Brooks presented the metaphor clearly and succinctly, describing principal features of the evolutionary process as generally understood in life sciences and extending them to the seemingly inanimate world of technological objects. Other biologically derived ideas were presented

as well, for example by Michael Sonis who suggested examining the usefulness of the competitive exclusion principal and principals of collective behavior, not based on optimization. There were other suggestions of this kind, but certainly no field represented seemed to be satisfied with its theoretical base.

At a general theoretical level, I was reminded of the statement by the late Elliot Montroll, a well-known American physicist, from 1978, that "Evolution is a sequence of replacements" [1]. That statement is, for the most part, consistent with research presented in the conference. There may be some examples to contest, but Montroll's assertion is the kind of theoretical hypothesis that might be used generally in diffusion studies. It also reminds researchers of the limits of focusing on only a single diffusion process in which a new technology replaces an old one. As Arnulf Grübler emphasized, evolution is composed of a series of interlaced and multiple diffusion processes, characterized by various driving forces and adoption environments.

Among the most promising directions for the search for theory appears to be the field of communications, as well as biology. In communication, the aspect stressed was networks. Networks were raised in different forms by several speakers, for example, Kirk-Jan Kamann and Peter Nijkamp from the Netherlands. Gerhard Rosegger talked about a particular type of network, the curious mix of formal and informal alliances that give shape to the global automobile industry. Hägerstrand mentioned the need to research the architecture of social communication and relayed the wonderful quote, "First I make friends, then I make business." There were also the AIDS examples (Emilio Casetti and Cindy Fan), which stressed very much the importance of networks. Here is an area in which the revealing of social networks over the last few years as the epidemic has spread has been readily apparent. Illumination may come from understanding communication in more detail, as manifested in spatial and other characteristics of networks.

The question of networks is intimately linked to the question of people's behavioral rules. A relevant insight comes from *The Book of the Courtier*, by Baldesar Castiglione, one of the first advisors to policy makers [2]. Castiglione did not emphasize analytic processes in explaining diffusion: "Usage is more powerful than reason in introducing new things among us and in blocking out old things and anyone who tries to judge of perfection in such matters is often deceived." That was published in 1528. Perhaps, as Marchetti would say, the rules of the game do not change very much.

The need to understand the filtering and acceptance of messages evokes a remark about causality. There was discussion at the conference, and I will return to this later, about the meaning of space or location. Åke Anderson raised the issue of space. Students of philosophy may remember that the 18th-century Scottish philosopher and historian David Hume had three principles of causation: first, temporal precedence of cause over effect; second, spatial contiguity; and third, constant conjunction. In the context of diffusion, it may be useful to revisit ideas about causation from philosophy and other fields. What are the underlying principles and requirements for the reproduction and spread of technology?

As mentioned already, another field that merits a careful "diffused" look is biology. It is clear that there are exciting developments going on in the life sciences that bear both directly and indirectly on diffusion. Within the discipline, there is a highly developed vocabulary of "passive" and "facilitated" diffusion, active transport, and membrane inhibitors. There is also potentially relevant work with regard to the role of messenger chemicals (of course, the messenger RNA). In neurosciences, there have been fascinating discoveries about so-called cell adhesion molecules that also transfer messages and guide cell–cell interaction.

Vladimir Rudashevsky commented in the conference that diffusion is a process of mutual exchange. That statement can certainly be fruitfully reflected upon by our biologist colleagues, who would probably agree and have many examples at the cellular and genetic level. Back at the level of human society, Marchetti made the remark that people diffuse in and out of scientific and other sectors based on the rates of difficulty and success in finding new things. As the effort to develop a theoretical basis for diffusion studies continues, individual researchers must look beyond their own disciplinary borders to areas of communication theory, biology, and other fields.

There was much discussion about the importance of diversity. Diversity again recalls biological issues, this time those current in the vast undertaking proposed to map the human genome. Most biologists think that much of the genome may contain little information, or is "junk" as the mappers sometimes say. There may be only particular segments, or sequences of genes, that are vitally important. There may be some metaphors here with economic and social processes that are worth exploring. Dosi and others noted the importance in economics of the heterogeneity of preferences, expectations, and competencies, and that the heterogeneity is required for evolution. What seems to be true at the genetic level needs to be understood and appreciated better at the economic and industrial levels.

Now this seemingly inefficient evolutionary model introduces some awkwardness for traditional economic theory. It runs counter to some of the preferred assumptions in economics for the last three or four generations about perfect information, rationality, and existence of equilibria. Another aspect that came through quite clearly in several talks is that the role of prices from a diffusion point of view is unclear. Prices convey certain kinds of information and send certain signals, but their roles and causal function from a diffusion perspective would seem to be less important, especially in the early phases of diffusion, than mainstream economic theory would indicate. What emerges is the importance of specific history, captured in the phrase that Brian Arthur [3] has popularized and that was mentioned by several speakers, including Yuri Kaniovsky, path dependence.

Castiglione was an early supporter of path-dependency. Let me share another quote, which relates to some of the marketing questions discussed in the conference: "Custom often makes the same things pleasing and displeasing to us. Whence it comes about that customs, dress, ceremonies, and fashions that were once prized become despised and contrariwise the despised become prized." History matters. Where you are will affect where you will be the next day. Where you are now is determined by where you were before. You do not and cannot reshuffle all the cards every day.

Continuing on these general issues of methods and theory, certainly one of the debates is about the literal use and exercise of curve fitting. Many examples of curve fitting are seen in the diffusion literature. There are simple examples taken from biology: for instance the growth-to-limits behavior of bacteria. There are the Fisher–Pry competition models. There are the multiple substitution models. There are logistic functions, Gompertz functions, and modified exponential functions. There are also questions raised about the applicability of each kind of curve fitting to each case. Moreover, does the curve fitting in practice usually apply to cases that are so simple as to be trivial? There is no resolution of that debate, other than to say use a model that makes sense and enjoy the fact that some simple relationships are deep and important.

Predictability

The sight of good fits of data and the scent of a theory raise hope of predictability. There was disagreement in the conference about the extent to which understanding of

diffusion enhances ability to predict. A majority was on the positive side, saying there is quite a lot of predictability, but there were several strong caveats. Haustein reported one example where prediction based on a diffusion theory failed. Was it a failure of diffusion theory in general or of a particular model or application? Robert Ayres presented a possible counterexample in the area of motor fuels, where the product under study did not follow a simple S-shaped path. John Tilton shared the problems of using diffusion for prediction in multiple substitution, with a case of six competing kinds of beverage containers. How strong are current tools in the face of real world complexity?

At the same time, there were promising papers about methods in predictability. Vacca and Valerio Franchina presented a method that is a virtually completely automatic procedure using triplets—three data points, including early data points out of the chaotic, turbulent, initial phase of technology innovation—to estimate growth processes, and showed several striking examples of excellent fits. They say it appears to be a more objective process than others that have been employed. Alain Debecker also presented some interesting rules of thumb about the accuracy of prediction, certainly handy for practitioners to use. The prerequisite for most analyses though is that the process already has to be visible, signaling to the human eye. There has to be a reasonably high level of signal. The crystal ball cannot be completely empty or cloudy. There has to be a reasonable number of data points in it. Underlying any look into the crystal ball are diverse views about the extent to which natural and social systems are chaotic, tending toward certain forms of (self-) organization, or more strongly deterministic.

Time and Space

The question of predictability naturally raises the question of time. Following is a quote from another distinguished physicist, Robert Herman. Back in the late 1940s and early 1950s, Herman and Ralph Alpher were responsible for predicting the background radiation of the universe, the black body radiation, which led to the Big Bang Theory. This was certainly a discovery that would reinforce the arrow of time. Herman is said to have commented subsequently, "Time is the disgusting coordinate of the universe." The conference participants heard a lot about time, mostly as a strict clock ringing the hours of diffusion.

Scientists who build models of the global climate talk about processes, like the changes in the ice caps, as having slow physics and other processes, like formation of thunder clouds and storms, as having fast physics. Social processes may also be said to have slow and fast physics. Whereas transportation infrastructures spread over intervals of 50 years or more, as shown by Nebojša Nakićenović, clothing fashions diffuse worldwide in a few months. In fact, it was suggested by Grübler that diffusion processes have a hierarchical structure, perhaps a fractal structure. Alternatively, there is a continuum of parameters on short and long time scales. To what extent is there measurable structure within the temporal dimension of technological diffusion?

Perhaps the most widely discussed feature of temporal diffusion is the bunching of innovations. Like a "baby boom," there appear to be periods of increased birth activity, when clusters of technologies are initiated together for certain reasons that we may not understand. Under what circumstances are there multiple innovations or clusters? Similarly, is there a focusing of diffusion phenomena at the end of certain time periods? On the one hand, there were proposals that there are bouquets of innovations and, on the other hand, there are forces that act as lenses or cones that appear to concentrate diffusion processes. So, there are most interesting phenomena in time. Of course, the question was raised if technological life cycles are becoming shorter. Is there an acceleration taking place such that each successive innovation spreads more rapidly? Is there an acceleration

taking place within the hypothesized 50-year "long waves" or pulses of economic growth such that innovations taking off later within such a time frame diffuse more rapidly?

Time is an important issue not only for research. Time is important because it has implications for equity. It is not only that everybody gets things, but who gets something first, that matters a great deal. The time issues are also important for education, as was raised by Maryellen Kelly and some others. There may be mismatching of technology diffusion processes with the educational system. To what extent does this mismatch stem from ignorance that might be overcome?

Returning to the issue of whether the average life cycle is becoming shorter, I, for one, am unconvinced by the evidence shared at the conference. It is possible there is such a shortening. However, the situation may be confused by an increase in the number of diffusion processes. To give an illustration, the typical supermarket in America now has an average of 18,000 items for sale, whereas 40 years ago it had 2000 items. It may well be that the life span of an average product has not changed much. However, because there are so many products, there is the illusion of acceleration. Perhaps changes in quantity and complexity of processes are being mistaken for an acceleration. This is a question that should be researched.

One more question in the time area relates to the notion of appropriability. This is the ability to prevent others from taking or making use of technology without authority or right and thereby relates to the capability of innovators to internalize some of the economic benefits of technical progress. Appropriability was raised several times by economists. Is appropriability just a diplomatic word used by economists for the control of diffusion over time? It seems to be a word that landlords would like and renters might not.

To turn from time to space, there was lively discussion about spatial diffusion. Helga Nowotny asked whether, when diffusion researchers talk about space, is the meaning of space metaphorical? The meaning appears to go beyond traditional geographical coordinates. Anderson talked about technology dissolving the role of contiguity. Several speakers, including Lawrence Brown, Hägerstrand, Kamann, and Sonis pointed out the need to examine spatial and temporal diffusion together. It was said that more complete coordinate systems are needed. This view recalls the question of networks. Clearly, spatial issues need to be revisited.

Yet, the traditional notion of space can still be important. There is the question, for example, of diffusion within the single Europe that is foreseen (Charles Edqvist and William Peirce). So, even as new kinds of spatial or space–time relationships are important, space by itself may still be meaningful. Anderson offered a reminder about the parts of the world that are not included in rapid diffusion. The relationship of diffusion and development is obviously critical. Sonis also emphasized special spatial niches, wombs, one might say, that are needed, areas where technological innovations take hold. The conclusion is that it would be a loss to abandon completely the study of space as simply metaphorical or illusory.

Innovation and Niche Definition

There was forceful debate about what is an innovation and what is a niche. Anderson warned about perils in theories based on ill-classified phenomena. There was also discussion about the differences between fundamental and incremental innovation. For example, there was debate about what is computer-integrated manufacturing (CIM), what is a flexible manufacturing system (FMS), and what is "just-in-time inventory." Are these innovations? If not, what are the boundaries of innovations? Certainly, such concepts are

not as clear-cut as are innovations in genetics or the invention of the automobile. Modelski, with his analysis of democracy as an innovation, raised more generally the question of forms of government and forms of social and institutional innovation.

The argument about niches had several facets. The work by Dominique Foray on metal casting raised the issues of the appropriate definition of the diffusing object and the relationship of the occupant to the niche. There is also the important question of how to modify the niche. The fascinating case of the car and the horse was presented. At first, the niche for the car is replacement of the horse. Then all the horses are gone, and the niche for the car becomes a new expanding niche that the car itself largely creates. In short, innovations and niches are themselves interacting and dynamic.

Selection Dynamics

Analysis of the population of innovations naturally leads to the issue of selection. Selection was addressed in a variety of ways. There is the canonical statement from the Bible, "Many are called, few are chosen." Mahajan said that the rule of thumb in marketing is that 70%–90% of all new products fail. Marchetti said that, from his studies looking earlier in the process, 1% of innovations succeed. Then the question is, what drives us to experiment under such bad odds? It seems crazy.

Silverberg pointed out that many innovations are inferior and more expensive than their competitors at the outset. Bruce Guile noted that perhaps the way out is to recognize the triumph of action over analysis. Maybe some combination of ignorance coupled to a general attitude of optimism begins to explain the yearly parade of bankruptcies. Dosi and Silverberg argued that diversity of expectations, including those that may lead to failure, are required to explain diffusion processes. Also striking was Theodore Modis' statement that studies done about the history of diffusion are usually the history of winners. It is a bloody history, and Modis suggested more effort in counting the casualties, the deaths, the lunatics, and losers. It is important to understand more about what has happened at the end of life cycles and in aborted processes.

Dosi made the perceptive comment that product markets select technologies, but financial markets select firms. The two processes are not identical. There were several papers relevant in this area. A paper by Charlie Karlsson that examined why enterprises adopt technologies emphasized information channels and frequency of exposure. In a way, his view is similar to a marketing perspective. Edquist looked at empirical differences in diffusion within the countries of the Organization for Economic Cooperation and Development and emphasized social and cultural factors. Kelly and Brooks offered a study in the manufacturing technology area trying to understand a particular sequence of adopters among firms. Of course, there is the question of the role of entrepreneurs. It would seem that there are many open questions in the area of selection.

Role of Marketing

By now marketing has been mentioned several times. Marketing is an attempt to change or modify selection. Marketing people may be considered true aspiring bioengineers of human society. But one may also raise the question whether marketing matters. We saw several comparisons between the Western economies and the Soviet Union with some strikingly similar diffusion data. One has to ask the question, given such different marketing and distribution strategies and channels, how is it that some results are so similar? Perhaps marketing is the pageantry, the flags flying in the procession of the king. To use a different metaphor, perhaps it is the navigation system for a largely preset trajectory. Marketing may only rarely change the niche to be filled.

It is also important to ask how marketing changes over technology life cycles. Thomas Lee raised this issue well. One idea is that it is necessary to market in pulses in order to fill successive niches, with information that needs to be distributed through time in certain ways. There were several comments, some flippant and others serious, about the importance of word of mouth. This appears to remain the dominant way for people to communicate decisively. Technologies may make the shelves of our marketplaces look modern, but diffusion processes may show how close today's humans are to our chattering, oral ancestors.

Cross-cultural comparisons would help show what is deeply similar and what is superficially different, given similar outcomes of diffusion processes. It should be possible to do revealing comparative studies of the effects of marketing strategies for the same products or technologies in different countries. In such studies, it would be useful to explicitly employ hypotheses from the diffusion literature. For example, one could explore reasons that early penetration may be associated with high ultimate levels of market saturation, while cases of later penetration are associated with lower ultimate levels of saturation, as found by Nakićenović in the analysis of diffusion of transportation technologies.

Social Aspects

Quite a few participants raised the question of social factors. Everyone recognizes that the diffusion of an innovation or several innovations can have many social effects. Several people noted that there are many causal chains leading to an overall effect. To give an example, automobiles, which were mentioned a number of times, replaced horses, diminished the number of stables, and reduced the number of flies and the amount of solid waste. They thus may have lessened somewhat the spread of communicable diseases. They helped the growth of suburbs. They reduced railroad traffic and transformed shipping. They changed the nature of the hotel business. They diminished the employment of domestic servants. They changed marketing areas. They caused international difficulty over oil resources. They affected rural life. They made drive-in movies and new kinds of vacations possible.

There were suggestions that more of the social dimensions of diffusion should be explored. At the same time, Silverberg and others made the point that social change represents the combined contributions of many inventions. Although the automobile made possible the suburbs, the suburbs may also have required the telephone. What is visible is almost always the result of an accumulation of influences, in many cases of smaller innovations. These smaller innovations are a significant part of the process. The force of any particular invention or innovation might be quite weak. The phrase that Silverberg used was the collective nature of technological progress. In fact, several participants referred to the notion of development trajectories and the concept of "technoeconomic paradigms" consisting of clusters of interrelated technical, organizational, and social innovations that has been associated with Christopher Freeman and Carlota Perez [4].

One issue that might be evaluated more in the future is a social, even a moral and an aesthetic, one. Diffusion itself (or competition) has countervailing effects, and the balance changes through time. On the one hand, diffusion is a force for homogenization. On the other hand, it multiplies difference. We have both the increase in the number of inventions and innovations and, at the same time, the possibilities for greater or wider standardization. In the discussion, people were sometimes talking about innovation and diffusion as something quite subversive that would overthrow and would change the

society. This was evident in discussions and papers of Soviet colleagues about innovation in the context of perestroika. At other times, there was a sense that technology and diffusion are a force of standardization, a conservative force in a certain way. These offsetting tendencies might be explored more. A starting proposition may be that fluctuation generates diversity, but propagation leads to homogenization.

Globalization

Another social, and also political and economic, issue that was discussed was that of globalization. This was raised by Hägerstrand, Lee, Marchetti, and Modelski. Two aspects of globalization were talked about. There is the global diffusion of technology, and there is the more specific process of technology transfer between nations. Research presented indicated that isolation of technology, technological protectionism, fails in the long run. Technology simply does diffuse globally. The question then is how much one can abet or retard it. In the East–West context, especially, are there more positive ways to handle the diffusion of technology?

At an abstract level, the issue may be phrased, is there a widely acceptable way for nations to capture income globally that is attributable to research and development? It appears that nations behave, or would like to behave, much like the successful firms described in the Silverberg model. It is therefore not surprising that there is growing international debate about equitable and optimal national levels of investments in R&D. It is the appropriability question in another guise or at a higher level of the system. The critical point is whether the diffusion of innovation and its benefits remain ordered in a civilized way, without wars and other violent conflicts referred to by Modelski and others.

In globalization, with regard to technology transfer the issue is "catch-up." To what extent can the introduction and diffusion of innovations be accelerated, especially to developing countries like China? Sergei Glaziev's paper included a good, provocative phrase, "the advantages of the backward." There is a need to understand better what the potential advantages of the backward are. Some examples of acceleration of diffusion processes were shown; these appeared to follow a kind of learning or experience curve in which late adopters were spared some of the timeconsuming experimentation of the early adopters. To what extent does this hold for sophisticated, as well as trivial, cases?

Ultimately, it must be asked, "After catch-up—what?" It is unrealistic to think that everybody, at some moment in future history, whether firms or countries, will be at a relatively even point in the adoption of technologies. It is even less realistic to expect that such parity could be sustained. Diffusion phenomena in a way seem to be elastic, with some leaders always pulling away, but then a pack of followers periodically coming nearer, only for a leader, sometimes a new one, to pull away. Although not frequently, the ordering of diffusion processes does change among nations, and the desire to take the lead is the essence of competition in politics, as well as business.

To return to the status of the less developed countries, one of the troubling features of the conference was that, although there is a large library of evidence on diffusion processes, quantitatively documented cases from developing countries are scarce. The past behavior of countries like the United States, Sweden, the United Kingdom, and increasingly the Soviet Union has been studied extensively. In contrast, there are few data and analyses from India, China, Argentina, and other such countries. On the empirical side it is urgent to do more work on less developed countries. It would help crucially to answer questions about whether and how catch-up occurs.

Applications

The last area for comment is applications of diffusion for policy, especially in firms and the national economy. The prospects for applications were addressed by several people, including Brian Sullivan and Guile. Judgments here are closely related to views on the predictability question. Sullivan points out that application of diffusion methods is itself diffusion and adoption. It might be called the diffusion of diffusion. Presumably there should be a competitive edge from employing the kind of ideas and analyses shared at the conference, at least until they reach saturation. There was debate about whether there is a vicious circle in use of diffusion research, in that if the information is widely publicly available, it may no longer be valuable. This debate resembles other debates about the value of information in markets.

At the same time, there are broader and probably useful guidelines about behavior related to diffusion that appear to emerge from the presentations and papers. For example, there is the evidence from Grübler and Nakićenović that late adoption is associated with fast diffusion, but a relatively low saturation level. There is also evidence of "seasons of saturation," when many diffusion processes concurrently reach their culmination and create both economic stress and windows of opportunity for initiation of new growth. Rudashevsky explored how such macro patterns of diffusion link to issues of restructuring or perestroika. Thus, at a conceptual level, there may be useful notions for policy and applications apart from specific predictions.

At the micro level, there are, however, potentially specific applications of diffusion analysis. Among these is the remarkably precise application from Vacca and Franchina in the AIDS area. The question is whether it would be socially robust to accept or use such a prediction. How much should it be relied upon? Should the health minister of Italy risk the entire government health care system on this prediction? Would even supporters of diffusion theory prefer to place, say, half of their resources on their own forecast and then diversify a little? Even if one has a high level of confidence in the diffusion-based prediction, strategically and tactically, how is it best to deal with this faith?

Both at the macro level and the micro level, the system almost always seems to keep away from homogeneity. Dosi made the playful comment that for growth it is important to have many economic agents grossly uninformed about the future. This appears to be a general prerequisite for evolution. It may also assuage any fears that experts may have that everyone will adopt or act upon their ideas. Linstone emphasized the benefits of multiple perspectives, or exploration of several paths. Shunsuke Mori provided a valuable caution about the extent to which one enterprise, or presumably one nation, can effectively manage the whole process from invention through innovation and diffusion. There may always be gaps between intention and performance in application, whether due to inherent capability or external surprise. The environment may be so turbulent that one is unable to pursue a strategy over a long enough period for it to matter.

Guile stressed the delicacy of timing for successful applications of diffusion analyses. He talked about possible mismatches, the need for matching time scales, and the need for the fertility of the receptor. To illustrate, here is a quotation about the fax machine, which has proliferated rapidly worldwide since about 1987: "One possible extension of electrical invention ... is facsimile transmission. Newspapers have been thus sent from New York to San Francisco ... Other uses of the same mechanism are for sending news pictures, identifications of criminals, x-ray photographs, weather maps, signed documents, chemical formulae, graphs and messages in other alphabets and symbols." This was an exactly correct statement by an analyst, technology assessor, and distinguished sociologist

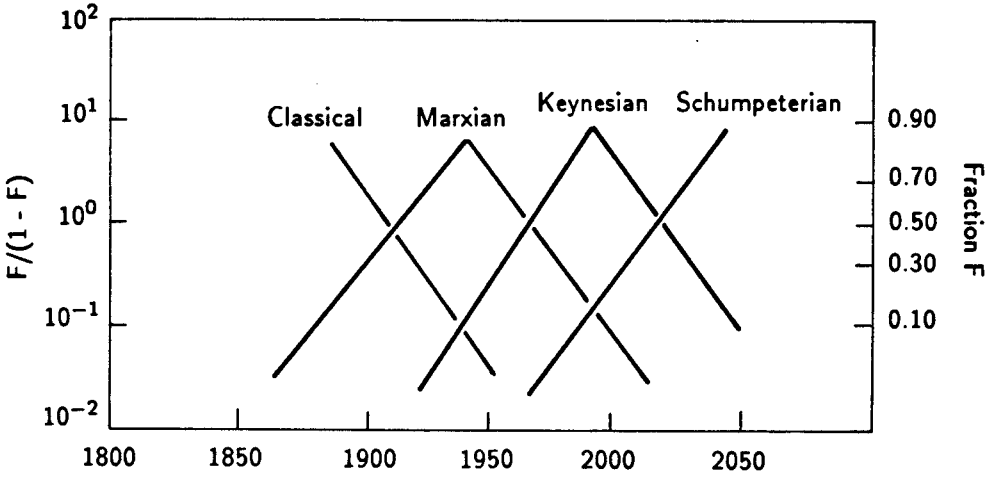

Fig. 1. Diffusion of technoeconomic paradigms.

... in the year 1933 [5]. Of course, the simple fax machine concept was 54 years too early from the point of view of diffusion. A related cluster of innovations, including high quality telecommunications, was required to potentiate the fax. Certainly, timing is critical in commercial application.

Finally, in the applications area, one must raise again the question that has been posed in the work of Henry Ergas [6] and was also raised by Edquist. At the government level, what specifically constitute "diffusion-oriented policies"? Peirce wondered whether governments have at their disposal appropriate policies that can influence diffusion processes at all. "Diffusion-oriented policies" is a most tempting term and needs to be explored and clarified.

To conclude, let me recall two of the best phrases used in the conference. One participant (Kamann) referred to diffusion processes as "rat-race dynamics." Another (Dosi) commented on the necessity for "crazy companies." Tilton asked the question what has changed in 20 years of diffusion studies in economics and other fields. My answer is that we have sorted a lot of order from the apparent chaos of social behavior, but have also recognized better the necessity of disorder, and we are trapped as ever in the race. But, as shown in Figure 1, our paradigm is gaining.

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