

**On Svante Lindqvist's changing Technological
Landscape**

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These comments on the paper by Svante Lindqvist, "Changes in the Technological Landscape: The Temporal Dimension in the Growth and Decline of Large Technological Systems" were delivered originally to the Wallenberg Symposium on Economics of Technology, arranged by Chalmers University of Technology and the Royal Swedish Academy of Engineering Sciences, in Marstrand, Sweden, on August 18-22, 1991. They have been revised for publication in the conference volume: Technology and Economic Change, O. Grandstrand and P. Jacobson, eds., to be published by Elsevier in 1994.

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The program organizers of this conference surely knew beforehand how thoroughly I would enjoy and appreciate the paper contributed by Svante Lindqvist. This is so because I am known to have an amateur's interest in elegant historical writing, and a pronounced weakness for writers who deploy deft metaphors -- as Lindqvist does in likening the technological historian's presentation of the technical context of material life to a painter's landscape. It also was easily predictable that I would harken to the call Lindqvist has addressed to historians of technology and economic analysts of contemporary technological issues, to give closer attention to the *diffusion* of new techniques, and the later phases of the life cycle of technologies that have become pervasive features of the material landscape.

Lindqvist's rightly points out that the pro-innovation bias of modern economic analysis must bear some of the blame for the difficulties he experiences when trying to stir interest in the subjects of technological maturation, obsolescence, and extinction. He must first pry his fellow-technological historians' attentions away from an almost exclusive absorption in chronicling the ways in which novel production methods and products have come to be created and first introduced into the market. One can sympathize with any scholar who in these times finds it necessary to combat the powers exercised by "Schumpeter's ghost", and so exorcise the demon of obsessive preoccupation with heroic inventors and innovating entrepreneurs.

Certainly I can sympathize, having experienced some similar sense of frustration with my fellow economists' recent fixation upon the virtues of doing almost everything conceivable to enhance the "competitiveness" of firms by promoting "innovation". It is sometimes hard to discern whether my academic colleagues are leading or following the current of business opinion in their choices of research topics, but it was the case that American corporate executives during the 1980s developed an obsession with the rhetoric of innovation, if not with the reality. Further subsidization of R&D, relaxation of anti-trust strictures against (so-called pre-competitive) research consortia, moves to curtail the legal rights of plaintiffs in product liability suits, strengthening of intellectual property protections, and still other policy initiatives all have been, and are to this day being carried forward

under the banner of "innovation policy". Some years ago I suggested (see David 1986) that the strength of the consensus behind "innovation policy" in the U.S. derived from a Reagan-era resistance to having the government appear to intervene in the present, and the comparative ease with which it was possible to form coalitions on behalf of an unspecified future.

Nevertheless, it must be said that an exclusive policy focus upon the generation of innovations blindly ignores the complex system dynamics of technological change, in which innovation and diffusion are interdependent processes that frequently operate in mutually reinforcing ways (see, e.g., David 1992). To call only for R&D subsidies, on the ground that the "appropriability problem" leads to private underinvesting in generating new technologies, is to close one's eyes to the possibilities that due to externalities and spillovers of various kinds arising from the learning involved in implementing novel techniques and organizational reforms, the market system may be failing to provide proper signals and inducements for firms to take upon themselves the costs and risks of *adopting* new technologies. It also disregards the connection between market experience with the introduction and acceptance of technological innovations and the readiness of individual and corporate investors to devote resources to R&D activities.

Of course, it would be an incorrect reading of the literature on the economics of technical change to conclude that economists had not been concerned with the theory and reality of the adoption of technological innovations. Lindqvist himself notes the classic contributions of Zvi Griliches and Edwin Mansfield, and any one of a number of more recent surveys would attest to the further development which this field has undergone in the past thirty years (see, e.g. the now slightly dated review in David (1986), and Dosi (1991)). In addition, it is not hard to find references to some admirable economic histories of the growth, elaboration and ascent to nineteenth century dominance of the steam engine in the field of industrial power technologies, of the steam railways and steamships in the field of transport technologies, of horsepowered farming machinery, the gasoline tractor, and many other case studies.

Still, Lindqvist is quite right to complain that virtually all the attention of economists, and the "new" economic historians who they have influenced, has been devoted to documenting and explaining the portion of the diffusion curve along which the extent of a new technology's use is rising. The conditions that bring about "saturation" -- when the extent of use ceases to increase, and the subsequent phase of the technology's decline in absolute and relative economic importance, are only rarely made the subjects of systematic

study. Two recent exceptions should be noticed, however. Poznanski (1986) examines the elimination of the Bessemer and the open-hearth processes of steel-making from use in the steel industries of a sample of 20 countries, in an attempt to identify empirical regularities in what he refers to as "the extinguishing process". Grubler (1990) has drawn together quantitative data for the principal modes of transportation, and traced the evolution of successive infrastructures (canals, railways, telegraph systems, etc.) beyond the phase of maturity and into that of abandonment. There is, alas, a small tragedy to be reported here, recalling *Spencer's* comment upon the pitiful circumstance of a beautiful theory being killed by an ugly fact: the findings of both these exceptional inquiries are sufficient to cast doubt upon the general validity of a strict construction of Lindqvist's "inverted U-curve theory". It is simply not the case that there is symmetry in the temporal durations of the formation and abandonment phases of the life cycle -- in the instance of these major, and historically pervasive technologies. In the case of the steel-making techniques, Poznanski (1986) concluded that the reduction of output from a specified technology was a less protracted process than the preceding expansion. That appears to be true also of the dynamics of the respective market shares in the cases of the canal, railway, and telegraph systems.

The same group of illustrative instances will serve, further, to bring out a conceptual drawback that the theory of the inverted U-curve shares with the mechanical theories of the classic S-curve of diffusion. Both encourage the tendency to treat specific technologies in isolation, and to draw upon inappropriate organic metaphors for "explanations" of the early phases of "vigorous growth", followed by "maturation", "senescence" and "decline" into disuse. We need, instead, to see the changing extent of use of particular technologies as the outcome of processes involving microeconomic decisions by producers, or consumers (in the case of product innovations) as to which among the available alternatives they should acquire, adapt, maintain, and extend. Technologies do not function in isolation, and in many instances they are forced to compete directly with substitutes for market niches. In the simple cases of binary competitions, where two rival production methods are available, it is understandable that economic analysis focuses upon the expansion phase of the story -- for, a complete account of the latter would, in each case, encompass the decline of the pre-existing technology. Much of the rapidly expanding literature devoted to the market processes through which *de facto* technological standards emerge in industries characterized by the presence of positive network externalities, has been formulated in the convenient terms of such binary competitions -- direct vs. alternating currents, QWERTY vs. the "Ideal" typewriter keyboard, PAL vs. SECAM television standards, Sony Betamax vs VHS formats for

videocassetts, DOS vs MacIntosh operating systems for personal computers, and so forth (see David and Greenstein (1990) for a survey of this literature). What reference to such situations should make evident is that the set of established technologies forms a crucial part of the social and economic environment within which an innovation must find its "niche", and eventually expand the domain of its application and influence. Old technologies are worth studying, therefore, even if the ultimate concern of the inquiry rests with the fate of the newer methods that may or may not supplant them.

So, with this range of motivations in mind, we can enthusiastically join Svante Lindqvist in urging a shift of emphasis away from innovation studies and toward diffusion studies on the part of historians of technology. Of courses, it is a good rule to let everyone find their own reasons for doing what you wish them to do, and I would not want to transgress it here. Undoubtedly, Lindqvist knows what he is doing in building a case to persuade his fellow historians. He points out that as we live with technological systems that are embodied in durable structures, and which are displaced only gradually by newer, competitive technologies, the historian is likely to seriously distort the picture of the material landscape of a past era by concentrating attention entirely on the novelties and portents of the future that were then emerging. Further, quoting David Noble, to the effect that "technology is hardened history, the embodiment of social relationships in the past," Lindqvist argues that the study of technologies that have survived from the more remote regions of the past -- and therefore which are to be seen only in the later stages of their active lives, affords the historian an invaluable tools with which to examine the past values and social presuppositions that those technical structures encapsulate.

Economists, however, may find these less compelling as reasons to shift their attention from the stages of invention and innovation to those of diffusion, obsolescence, abandonment and extinction. The disciplinary difference in this regard seem worth pointing out, inasmuch as it may result in a corresponding difference in the specific developmental phases of technological systems that is subjected to most intensive examination.

For economists and economic historians concerned with long term economic growth, the diffusion of technological innovations is, or should be an essential part of the research program because technological change has been the prime source of sustained improvements in material well-being, and because new products and processes are incapable of having any material effects upon human welfare (positive or negative) unless they are brought into use. The connection between the improvement in productivity and the adoption of cost-reducing process innovations is a reasonably straightforward case in point. But there is a little twist

to it, nevertheless: it does not follow that an industry's productivity will be growing fastest when a new technology is being taken up most rapidly.

A simple bit of analysis of the movement of industry-wide productivity considered as the weighted average of the constant productivity levels characterizing a "recent" technique and an "old-established" technique (the former having a productivity advantage) is sufficient to demonstrate this. The full details are available elsewhere (see David (1991: Technical Appendix)) for those who wish to consult them, so I need only state the formal result clearly here. For the sake of clarity, several definitions are in order: we may measure the "extent of diffusion", $D(t)$, as the proportion of industry output produced with the "recent" technique -- a variable which, I suggest, corresponds to Lindqvist's notion of a "volumetric" measure of the importance of a particular technology. Then we can define the "speed of diffusion" as $dD(t)/dt$, and the "rate of diffusion" as the proportionate rate of change in $D(t)$, i.e., $\{dD(t)/dt\}/D(t)$. Now, it will be true in general that the rate of productivity growth in the industry will attain its maximum only after the point when the rate of diffusion has peaked. In the case of a symmetric diffusion process that followed a logistic, S-shaped path, the peak in the growth rate of productivity also would come after the peak "speed of diffusion" has been obtained, which occurs when the extent of diffusion reaches the 50% mark.

But, the foregoing demonstration assumes that the relationship between the productivity levels characterizing the recent and the old-established techniques is unchanging, whereas it is more generally the case that innovations undergo absolute and relative improvement in functionality (and reductions in supply price) as experience with their application accumulates. Because the continuing process of a technology's elaboration through incremental innovations is bound up in this way with its diffusion into use, and the further widening of the circle of adoption is often predicated upon those incremental improvements, the phase in which an innovation makes its maximum impact upon the rate of industrial productivity growth tends to be deferred still later. What all this implies is that if we are interested in the technological developments underlying the upwelling of productivity in the economy -- and this holds for both partial (e.g., labor) productivity and total input productivity measures alike, then we need to be studying what is taking place when a comparatively new, but far from wholly novel method has already become quite widely adopted and is having to make headway against a previously well-entrenched substitute system.

Yet, if the process is one that is expected to continue, we cannot ignore where the next innovation will come from, and whether it, in turn will be able to gain a foothold in the

territory that the now ascendant challenger is coming to dominate. Innovation and diffusion are intertwined historical processes, and they cannot properly be understood in isolation from one another (see David and Olsen (1986), David (1992)). The remedy for past historiographic deficiencies is then the same as the one I would prescribe for the defects in the traditional analytical treatment of these subjects by economists: rather than oscillating between emphasis now on one, and now upon the other, let them be studied together as interdependent features of the complex system of technological change.

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