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Path Dependence, Lock-In, and History

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Abstract

Do economies and markets make remediable errors in the choice of products? Does the economy "lock-in" to these incorrect choices even when the knowledge that these choices are incorrect is readily available? The literature of path dependence may be understood to argue that these lock-ins and errors occur, even in a world characterized by voluntary decisions and individually maximizing behavior. In this paper we examine path dependence and illustrate three different forms of the term, each having a different implication regarding market errors and lock-in. Two of these meanings are common in the economy but provide no support for the claims that remediable errors occur. The third meaning, which does imply irremediable error, we show to be based on restrictive assumptions that are likely to be overcome in the real world. The analysis is illustrated by examining the market's choice of videorecorder formats.

Path dependence has been offered as an alternative analytical perspective for economics, a revolutionary reformulation of the neoclassical paradigm. Brian Arthur, a leading figure in this literature, distinguishes between "conventional economics," which largely avoids increasing returns or path dependence, and the "new" "positive feedback economics," which embraces them (Arthur, 1990:99). Before we stroll too far along the path dependence path, however, it makes sense to stop, take stock, and figure out where that path is leading us.

The claim for path dependence is that a minor or fleeting advantage or a seemingly inconsequential lead for some technology, product or standard can have important and irreversible influences on the ultimate market allocation of resources, even in a world characterized by voluntary decisions and individually maximizing behavior. The path dependence literature comes to us accompanied and motivated by a mathematical literature of nonlinear dynamic models, known as chaos or complexity models, for which a key finding is "sensitive dependence on initial conditions." Analogously, a key finding of path dependence is a property of "lock-in by historical events" (to echo the title of Brian Arthur's influential paper), especially where those historical events are "insignificant." If such path dependence does occur, it means that marginal adjustments of individual agents may not offer the assurance of optimization or the revision of

suboptimal outcomes. In turn, this implies that markets fail. Although not all phenomena that have been described as path dependence imply market failure, these normative concerns have been a prominent part of the path dependence literature.¹

In this paper we identify three distinct forms of path dependence. Two of these forms -- which we define as first- and second-degree path dependence -- are commonplace, and they offer little in the way of an objection to the neoclassical paradigm. Only the third and strongest form of path dependence significantly challenges the neoclassical paradigm, and as this paper shows, the theoretical arguments for this form require important restrictions on prices, institutions, or foresight.²

Unfortunately, the three discrete forms of path dependence are often conflated in the literature. When things that are different are grouped together and treated as things that are similar, error is assured. In this case, the error is transferring the plausibility of the empirical and logical support for the two weaker forms of path dependence (first and second-degree) to the strongest implications of third-degree path dependence. In fact, although it is fairly easy to identify allocations, technologies, or institutions that are path dependent in some form, it is very difficult to establish the theoretical case or empirical grounding for path-dependent inefficiency. .

1. Defining Path Dependence

There are three possible efficiency outcomes where a dynamic process exhibits sensitive dependence on initial conditions. First, this sensitivity might do no harm. That is to say, initial actions, perhaps insignificant ones, do put us on a path that cannot be left without some cost, but that path happens to be optimal (although not necessarily uniquely optimal). For example, a capricious decision to part one's hair on the left may lead to a lifetime of left-side parting, but the initial urge to part on the left might capture all there is to be taken into account. On a grander scale, a decision to use a particular system for powering the machinery in a plant may be a controlling influence for decades, but the long-term effects of the decision may be fully appreciated by the initial decision-maker and fully taken into account. We will call instances in which sensitivity to starting points exists, but with no implied inefficiency first-degree path dependence.

Where information is imperfect, a second possibility arises. Where this is the case, it is possible that efficient decisions may not always appear to be efficient in retrospect. Here the inferiority of a chosen path is unknowable at the time a choice was made, but we later recognize that some alternative path would have yielded greater wealth. In such a situation, which we will call second-degree path dependence, sensitive dependence on initial conditions leads to outcomes that are regrettable and costly to change. They are not, however, inefficient in any meaningful sense, given the assumed limitations on knowledge.

Related to this second type of path dependence is third-degree path dependence. In third-degree path dependence, sensitive dependence on initial conditions leads to an outcome that is inefficient -- but in this case the outcome is also "remediable."³ That is, there

exists or existed some feasible arrangement for recognizing and achieving a preferred outcome, but that outcome is not obtained.

The three types of path dependence make progressively stronger claims. First-degree path dependence is a simple assertion of an intertemporal relationship, with no implied claim of inefficiency. Second-degree path dependence stipulates that intertemporal effects propagate error. Third-degree path dependence requires not only that the intertemporal effects propagate error, but also that the error was avoidable.

The essence of the distinction between third-degree path dependence and the weaker forms is the availability of feasible, wealth-increasing alternatives to actual allocations, now or at some time in the past. The paths taken under first- and second-degree path dependence cannot be improved upon, given the available alternatives and the state of knowledge. Third-degree path dependence, on the other hand, supposes the feasibility, in principle, of improvements in the path.

Third-degree path dependence is the only form of path dependence that conflicts with the neoclassical model of relentlessly rational behavior leading to efficient, and therefore predictable, outcomes.⁴ In instances of third-degree path dependence, outcomes cannot be predicted even with a knowledge of both starting positions and the desirability of alternative outcomes. In a world where efficiency cannot successfully predict outcomes, some (most?) outcomes must be inefficient.

a. Illustrating The Concepts Of Path Dependence

One story that has been put forward in casual discussions of path dependence is the competition between Beta and VHS. There is a common perception, repeated in several papers (e.g. Arthur 1990: 92) that Beta was superior to VHS, and the market's choice did not represent the best economic outcome. We can use this story to illustrate how these forms of path dependence might be associated with a real case. In section V we will return to this case, presenting its actual history as an application of several of the ideas presented in this paper.

Home users of video recorders benefit from compatibility with other home users. Compatibility allows them to exchange recorded materials with other people and allows participation in the rental market for prerecorded movies. VHS is now the dominant format for home video recording. Thus consumers choices of videorecorder formats may exhibit path dependency: decisions by earlier adopters can be expected to have some effect on the decisions of later adopters.

Different constructions of this case would lead to different claims of path dependence. The first is to assume that VHS and Beta were basically identical and that the eventual market choice of VHS was arbitrary. One thing led to another -- the network effects of video recorders implied that some format would gain control of the market. This claim's relevance to economics is only that an initial arbitrary choice led to something significant and durable, and that if we were to look to our efficiency models alone we would not be

able to explain the choice of VHS over such alternatives as Beta. Efficiency models cannot be expected to predict which of several equally efficient possibilities will be chosen. If this randomness is the full claim that is made for this case, the choice of VHS would be an instance of first-degree path dependence.

If, however, we go further, to claim (counterfactually, as we show in section V) that VHS was notably inferior as a videotaping format, we make a case for one of the stronger forms of path dependence. We might claim, for example, that Beta was revealed over time to have been a far better format for special effects and quality of picture, that when the initial consumers made their choices they did not realize that Beta would soon allow 5 hour tapes. That is to say, during the time that VHS came to dominate the market it was not known that Beta would be better in the future. After the fact, it may appear that choosing VHS was a mistake, although it was not a mistake given the information that was available at the time. This is second-degree path dependence.

If we go still further, and claim that at the beginning, sufficient information existed to determine that Beta was superior, then we make a claim of third-degree path dependence. Such a thing might have occurred if, at the time that VHS came to dominate the market, most consumers had a preference for Beta, but each consumer was unaware that others had similar preferences. In that case, a slim lead for an inferior VHS format might have been propagated into eventual market dominance. Alternatively, if it were widely understood today that switching to Beta has a benefit greater than the cost, but we remain mired in the VHS standard, we would have another instance of third-degree path dependence.

Third degree path dependence is a dynamic market failure that is brought about by the persistence of certain choices. Of course, market failure in this guise would raise all the questions that it raises in static contexts. We would have to ask why no arrangement was made to bring about consideration of all costs and benefits. If our only answer were that such arrangements are too costly -- perhaps requiring a determination of the plans of all possible VCR consumers -- then we would not really have a feasible alternative allocation. Since the costs of making these arrangements are not different from any other costs, we would conclude that the costs of switching formats exceed the benefits. 5

Where does this leave the third-degree form? If we were presently using the wrong format, a possible claim is that we should now switch to Beta, that there is a feasible arrangement that would make everyone better off if everyone did so. The move has yet to occur, perhaps because each consumer prefers VHS, given that all other users have VHS. Here we would have a coordination problem of the sort that has been identified in a number of different circumstances.⁶ Alternatively, the third-degree form would apply if there had been a feasible improvement available at some time in the past, even if none exists today.

b. Mathematical Counterparts, Memory, And Definition

One confounding feature of discussions of path dependence is that the term has established meanings in branches of mathematics that some economists have encountered. The meanings are all related to each other, however, and the construction of path dependence from probability theory is analogous to uses that relate to lock-in.

Economists usually first encounter the term path dependence as it relates to integrability conditions. That use is somewhat removed from our present concern, but even there path dependency may be understood as irreversibility, which is not unrelated. A closely related development is the literature of hysteresis in economic variables.⁷ The meaning closest to the current use in economics is that of stochastic processes that incorporate some concept of memory, as in the following:⁸ Consider a sequence of binomial choices between two mutually exclusive outcomes A_1 and A_2 . The probabilities of each [either] occurring on the n th trial are P_n and $(1 - P_n)$ respectively. Writing the event in the i th trial as E_i , the probabilities may be written $P_{n+1} = f(P_n, E_n, E_{n-1}, \dots, E_1)$. The response probability is said to be " d -trial path dependent" where the probability function can be written $f = f(P_n, E_n, E_{n-1}, \dots, E_{n-d})$. In the special case where $d = 0$, the process is "path independent" (see Arthur 1987: 295, for a consistent usage).

The use of path dependence in economics is, for the most part, loosely analogous to this mathematical construction: Allocations chosen today exhibit memory; they are conditioned on past decisions. It is where such a mathematical process exhibits "sensitive dependence on initial conditions," where past allocations exhibit a controlling influence, that it corresponds most closely to the concerns that economists and others have raised as problems of path dependency. In such a case, "insignificant events" or very small differences among conditions are magnified, bringing about very different outcomes. It is that circumstance that yields both the "non-predictability" and "potential inefficiency" that Arthur (1989: 116) posits as important properties of increasing returns systems, suggesting both the positive and normative research programs associated with path dependency.

We turn now to a statement of path dependence for economic allocations that exhibit this characteristic of memory and then consider the associated meanings of any potential inefficiencies that may be implied.⁹ An allocation process exhibits path dependence if an action a_0 from the set A_0 taken at some time t_0 affects the set of choices A_n that are available at some later time t_n . We define first-degree path dependence as the simple assertion that this intertemporal relationship exists. First-degree path dependence carries no implication that the dependence on initial conditions results in any inefficiency. Action a_0 can be said to be path efficient where there is no alternative action $a_1 \in A_0$ such that the discounted present value of the total net benefits of selecting a_1 are greater than the discounted present value of net benefits from a_0 .

Any economy with durable characteristics exhibits path dependence in at least this form. What we have today is in part a consequence of what we had and what we did yesterday. We inherit a capital stock. We also inherit language, customs, laws, grudges, skills -- the wealth of nations. Such a concept is as old as economics. All dynamic models that specify a capital stock that is constrained to change according to a continuous differential

equation use this notion of path dependence. So too does the short run concept of variable costs: A firm with fixed assets will continue to use an inferior technology where the average variable costs of the old technology are lower than the average total costs of the new. Under such circumstances, the old firm might be considered "locked-in" to this inferior but still more profitable technology, exhibiting a first-degree form of path dependence.

Second-degree path dependence occurs where an action is taken that subsequent events reveal to be inferior to some alternative. Where information is imperfect, it is inevitable that some durable commitments are shown to be inferior as information is revealed with the passage of time. This problem of imperfect knowledge is present with any action, but it is highlighted by attention to intertemporal paths, especially under conditions of sensitive dependence on initial conditions. The choice of a_0 is ex ante path efficient if at each time t_0 there is no known alternative action a_1 A_0 that would provide a greater discounted social benefit than a_0 . In contrast to simple path efficiency, this leaves open the possibility that at some $t > t_0$ it is revealed that there was some action a_1 A_0 that could have been undertaken at t_0 which would have provided greater discounted social benefits than a_0 . Second degree path dependence then would be said to occur where actions are only ex-ante efficient. While actual outcomes under second degree path dependency may prompt some (naive) regret, seeming inefficiencies are not remediable; the existence or superiority of alternative paths are not known at the time that initial decisions are made.

Second-degree path dependence may occur as the consequence of imperfect foresight. Everyone maximizes, individually and collectively, given their current knowledge, but current knowledge is deficient. Values of state variables cannot be predicted solely from information regarding an initial endowment, preferences, and the state of knowledge. To explain or predict where we are today, we would have to know what was incorrectly "known," or at least anticipated, in the past -- i.e., the history of our ignorance.¹⁰

Second-degree path dependence may also have its origins in the real limitations of institutional arrangements. In some instances the costs of institutional change will preclude adjustment even where experience reveals preferable alternatives.¹¹

Third-degree path dependence occurs if an action is ex ante path inefficient, which means that at some time t_0 there is an alternative action a_1 A_0 such that the discounted present value of the total social benefit of selecting a_1 instead of a_0 are known to be greater than the discounted present value of costs, yet the action a_0 is taken. ¹²

There may be good reasons to suppose that inefficiencies would occur where there is this condition of sensitive dependence on initial conditions. After all, in these cases agents are making seemingly minor decisions that have major consequences. The path dependence literature puts forward several reasons that might explain why, even when all relevant costs and benefits are recognizable, the wealth-maximizing path might not be chosen. In one way or another, these reasons are all related to market failures: Some markets do not exist; some of the affected parties are not yet born; some economic actors cannot coordinate.

There are, however, important reasons why the simple condition of sensitive dependence on initial conditions does not make the case for market failure. First, agents making "small decisions" may well be confronted with all the consequences of their action, as we will consider below. Second, the losses implicit in any path inefficiency may prompt individuals to seek better arrangements. Finally, the trouble caused by sensitive dependence that is not remediable by private action may not be remediable in any other way..

2. What Forms of Path Dependence Are Implicit in the Literature?

Brian Arthur's (1989) consideration of path dependence is couched in terms of "lock-in by historical events." In his examples of the workings of positive-feedback models, which we examine in detail below, he finds that path inefficiency is possible where there are increasing returns. In this regard, Arthur's version of path dependence is the third-degree form -- as long as the information regarding payoffs is available to relevant decisionmakers.

The state of knowledge plays an explicit role in Robin Cowan's (1991) consideration of competition between "technologies of unknown merit." In his model, private agents or social planners try alternative technologies. Lock-in is fostered by two effects: Each trial of a technology provides experience in that technology, increasing the payoffs to that technology in subsequent trials; and each trial of a technology decreases uncertainty about its merits. In this context, it is possible that the technology that is adopted is the one that, according to the hypothetical "true" densities of the performance distributions, is inferior. 13

The situation that Cowan describes would appear to be a case of third-degree path dependence. Cowan's hypothetical social planner internalizes the benefits of experimentation, possibly avoiding undesirable lock-in. Thus Cowan's model specifies a failing of decentralized markets that is, in principle, remediable.

In recent years, examples and discussions of path dependence have proliferated in the literature. Mokyr (1991) discusses the connection between biological contingency and path dependence in economics, presenting instances that appear *ex post* to be mistakes, instances of second-degree path dependence.¹⁴ Roland's (1991) conclusions that the economic institutions likely to evolve in the Soviet Union will be influenced by the set of preexisting institutions are at their most basic level of the first-degree type, sometimes of the second-degree (should Russia emulate Japan or the U.S.?) and sometimes the third-degree (keeping a large state sector as a "very inefficient form of social security").

Although he did not use the current terminology, Schelling anticipated some of the kinds of problems that are considered in the path dependence literature. He discusses as "interactive behaviors" problems in which outcomes depend heavily on the order in which actions occur. Inferior outcomes may prevail in these cases, even in the face of known preferred alternatives, illustrating the third-degree form (1978 pp. 36-8). Schelling offers these cases, however, as examples of non-market behavior, and he also notes that

market institutions often arise as remedies for these problems (p. 33). Elsewhere he acknowledges the unfeasibility of some hypothetical improvements (p. 132).

The archetypal case of path dependence has been, of course, the configuration of the typewriter keyboard. As Paul David (1985) presented this history, the standard "QWERTY" keyboard arrangement is dramatically inferior to an arrangement offered by August Dvorak, but we are locked into the inferior arrangement by a coordination failure: No one trains on the Dvorak keyboard because Dvorak machines are hard to find, and Dvorak machines are hard to find because no one trains on Dvorak keyboards. The process is said to be path dependent in that the timing of the adoption of QWERTY, and not its efficiency, explains its survival.

Our 1990 paper demonstrates that the QWERTY case is highly problematic, but our concern here is with the rhetoric of this case. Some of David's claims for this case do not go beyond first-degree path dependence. His observation that "One damn thing leads to another" (David 1985, p. 332), is readily acceptable because it claims no more than first-degree path dependence. But David makes stronger claims. In accepting and repeating the claim that the cost of retraining in Dvorak is recovered ten days after the start of training (p. 332), for example, he positions the QWERTY case as an active example of third-degree path dependence. David's 1985 paper concludes: "Competition in the in the absence of perfect futures markets drove the industry prematurely into standardization on the wrong system where decentralized decision making subsequently has sufficed to hold it" (emphasis in original). We stay with the wrong keyboard, according to David, not because sunk investments in QWERTY make the switch to the Dvorak arrangement an inferior choice, but because of "decentralized decision making." This attribution of the error to decentralized decision-making clearly suggests that alternative, presumably centralized, decision mechanisms would correct this error. This is a third-degree claim. As is often the case, David's reader is likely to find the claim of path dependence in the third-degree form to be more palatable because of his earlier establishment of weaker forms of path dependence.

3. The Impact of Increasing Returns.

The importance of path dependence would appear to reside in the third-degree form. While there will be occasional and interesting instances in which analysis reveals an unexpected intertemporal effect, the overwhelming share of first and second degree dependencies will be garden variety durabilities that are well incorporated into economics. But if it is third degree path dependence that offers a "new economics," the question arises: Does such a phenomenon exist, and if so, what conditions bring it about? The answer offered by Arthur and others is that undesirable lock-in is a likely consequence of increasing returns. We turn now to that proposition.

We base our discussion on an example provided by Arthur (1989) that has the advantages of simplicity, clarity, and concreteness. This example deals with a choice of technologies, but it really is quite general. It could, for example, describe a choice between alternative locations where there is a spatial agglomeration economy. Though very simple, this table

illustrates the paradigmatic case for the impact of increasing returns. The table below reproduces Arthur's Table 2, showing the adoption payoffs for agents from adopting one of two available technologies. <<http://www.pub.utdallas.edu/%7EEliebowit/table.jpg>>

In this example, an initial adopter is presumed to know that he will receive a payoff of 10 if he adopts technology A, versus a payoff of 4 if he adopts technology B. In such circumstances, Arthur claims, the initial adopter will choose A. Subsequent adopters are still more likely to adopt technology A, since the advantage of being a subsequent adopter of A over being the first adopter of B only increases. So A is chosen, and its dominance is stable: There is no tendency for the choice of technology to shift to B.

The example illustrates undesirable lock-in because A is not the better choice if the eventual number of adopters is large.¹⁵ Depending upon assumptions about the state of knowledge, this path inefficiency may exhibit third-degree path dependence. Lock-in to A would exemplify third-degree path dependence if the information in the table were known. On the other hand, the choice of A is not an instance of third-degree path dependence if no one in society has the information that is in the table.

Arthur does not specify what agents know or how agents might determine their payoffs. We might construe them as knowing the whole table, or parts of it, or none of it. But the existence of this information is crucial for the determination of the eventual choice of technology, and also for the type of path dependence implied.

We consider two distinct interpretations of the payoffs in the table.¹⁶ In the first, the numbers in the table are taken to represent equal payoffs to each adopter, given the ultimate number of adopters, regardless of when each adopter makes his decision. That is to say, the payoff for early adopters changes as the number of later adopters changes. In this case, B becomes the superior technology when more than thirty adoptions occur. In the second case, the numbers represent the payoffs only to the marginal adopter, with all inframarginal adopters forever receiving the payoffs available at the moment of their adoption, in which case B becomes the superior choice only when more than fifty adoptions have occurred.

a. All Payoffs depend on the ultimate number of adopters

For now, assume that at any moment all the adopters enjoy the same payoff, that is, the values in the table represent the surpluses that are available to all adopters when any given number of adoptions have taken place. Although Arthur has stated that this is not his view of the table, it is an assumption that fits in best with many supposed instances of path dependency. For example, in the selection of a standard, an adopter benefits if he is later joined by other adopters. Agglomeration economies tell a similar story -- one's payoff depends on the final number of adopters.

Given this interpretation and the numbers in the table, can it be concluded that technology A, the "wrong" technology is chosen? In general, it cannot. For example, if the information in the table is known to adopters (as they are to Arthur's hypothetical

outside observer), each adopter would attempt to forecast the eventual number of adopters and the resulting best technology. In this instance, we cannot assert how agents will behave without specific assumptions about the role of expectations. Where agents have full information, there is no problem of lock-in to inappropriate technologies. Where the number of prospective adopters is greater than thirty, all agents can see that B will eventually offer greater rewards, and everybody knows what everybody knows. It is a Nash equilibrium that agents pick the solution that is optimal, given the number of adopters. For instance, suppose everyone knows that VHS is better when there are a large number of VCRs sold, and everyone knows there will be a large number of VCRs sold. Everyone would choose VHS. There is no lock-in to an inferior technology.

Some deficiency in information is required for lock-in to an inferior technology to occur. Yet that deficiency must not be complete if the lock-in is remediable. If no one knows the payoffs to the technologies except for hypothetical omniscient observers, at most we have an instance of second-degree path dependence. (Similarly, it might be argued that if no one in the economy is aware of the potential returns to a technology, it cannot be argued that the technology has been discovered in any meaningful sense.) Remediable lock-in to the wrong technology, or third-degree path dependence, requires that some agent(s) in the economy has, or could obtain, the information required to make a correct choice. And even where that occurs, third-degree lock-in is not assured, since the knowledgeable party(ies) might coordinate the choice of technology, especially since it should be profitable to do so. One likely strategy for such a party would be to acquire the technology at a price that reflects the prevailing expectations and appropriate some of the gain from such coordination.

Thus, in order for third-degree lock-in to occur, there must be agents who know enough to make correct choices but who fail to take advantage of the implied profit opportunities, and at the same time, adopters who generally know nothing more than the payoff going to the next adopter. These are very restrictive conditions.

b. Individual Payoffs Depend On The Number Of Prior Adopters

The alternative interpretation of this table is that early adopters never come to enjoy the high returns of a later adopter. Under this interpretation, each adopter's payoffs are determined solely by the number of prior adopters, and not at all by the number of later adopters. This interpretation might apply readily to technology choices where early movers have additional costs of developing a technology, or pioneering costs in a geographic area that later movers avoid.

Again, assumptions about what adopters know are crucial. If adopters are aware of the complete table, or even just the general trend of the payoffs in the table, then they must also be aware of a decision that is as fundamental as the choice between A and B: the best time to adopt. According to the table, there is a payoff to waiting. Given these payoffs, who would want to be an early adopter? If the table tells the full story of payoffs, there is never an advantage to going first. Some additional structure, or some additional mechanism is needed to explain the adoption of any technology at all. As we discuss in

the next section, the very considerations that solve the adoption timing problem also bear on the problem of choosing among technologies.

Of course, it might be that agents are not aware of the payoffs in the table, or even of the trend as the number of adopters changes. If no one has any information at all, then the choice of technology is unpredictable, but in this case the "superiority" of a technology is also something of an imaginary notion.

Only when agents know nothing except their current individual payoffs in choosing technology A or B will they unhesitatingly enter the market, and then they will incorrectly choose A. But in order for the choice of A to be an example of third-degree path dependence, it is necessary that someone in the economy knows that B is better. And for such a lock-in to occur, it is also necessary that the knowledgeable party does not manage to turn this knowledge into profit by coordinating buyers (or selling the information to them). These again are very restrictive assumptions.

3. Market Mechanisms and Path Dependent Processes

Where the restrictive informational assumptions required for third-degree path dependence are satisfied, the problems foretold by the table may still be overturned by any number of possible market responses, including investment in brand name, patent, and early market share commitments. Such market responses are, of course, absent from the table, but they nevertheless may constitute a significant rearrangement of incentives.

To see one way that markets address lock-in, in the following assume that payoffs depend on the number of prior adopters (as in section IIIb. above), and that adopters have some knowledge of the table of payoffs. Further, to consider these issues with a more convenient vocabulary, for the moment take Arthur's table to be the payoffs to firms that locate at one of two geographic sites, A or B. As a result of agglomeration economies, payoffs increase with the number of firms that choose each location. These are, of course, the increasing-returns conditions that are held to bring about lock-in. But there are two questions that arise here. First, given the pattern of returns, how does either location attract any firms, given that there appears always to be a return to delay? Second, which location prevails? As is shown in the following, the very same avenues of appropriation that solve the problem of who goes first are the mechanisms that can assure the choice of an efficient path.

The solution to the problem of getting any firms to locate at any location comes fairly readily. It is land ownership. In the familiar Ricardian or Von Thunen framework, any unique advantages of a particular location accrue to the landowner as site rents. Under conditions that are reasonably likely, owners of land can expect to extract the rents created by any locational advantages that eventually attach to the land. Where agglomeration economies are fairly localized, as in the conventional urban model (q.v. Mills 1967, Henderson 1977), a "pioneer firm" can appropriate the rents that result from agglomeration economies by acquiring all the land in close proximity to the initial plant.

Alternatively, ownership of other unique resources, such as transportation facilities, may constitute opportunities to internalize the agglomeration economies.

Someone must capture and, to some extent, redistribute these rents, or else payoffs like those in the table provide no way of getting started: Everyone wants to go last. Ownership internalizes the externality that is implicit in the table. Land owners have incentives to offer adequate inducements to potential early entrants. They can offer long-term leases at lower rents, or subsidize infrastructure, or even pay direct subsidies to early arrivals. Rewards offered to initial entrants will be recaptured out of the larger surpluses generated by subsequent entrants. The exogenously determined rewards posited in Arthur's table thus can be understood as incorporating artificial rigidity of incentives or inflexible prices of productive inputs and outputs.

The solutions to the starting problem, foresight and ownership, also are involved in the determination of which location prevails. City A and city B are competing with each other. At all times, the rents that can be extracted in one city will be limited by the benefits available in the other. A principal landowner in city B could attract an initial entrant by offering a subsidy, or could undertake the agglomeration economy activity at an initial loss. Similarly, a principal landowner in city A could compete by cutting rents or by providing subsidies to initial entrants. Clearly the landowner in city B will have to discount much further to attract an initial entrant, but just as clearly, the total wealth that can be created by situating the agglomeration-economy activities at B is greater than the wealth created by situating these activities at A. If the ultimate number of entrants were expected to be 100, a monopoly landowner at A could profitably invest no more than 1,450 as inducements to entrants, while a monopoly owner at B could profitably invest up to 2,090. 17

As in other circumstances, free rider and holdout problems may be important. But in a circumstance like the one presented in the table, all other things equal, the site that creates more wealth will have an advantage over a site that creates less. Owners at site B can be less perfect at overcoming their appropriation problem than owners at A and still win the competition.

Extending this analysis back to the choice of technologies, networks, or standards requires only that we extend the idea of ownership. Ownership of a technology can take various forms including ownership of critical inputs, patent, copyright, and industrial design. Literal networks such as telephones, pipelines, and computer systems are most often owned by private parties. Standards are often protected by patent or copyright. Resolution of these problems may be an important and as yet not fully recognized function of the patent system and other legal institutions. 18

4. An Alleged Case of Path Dependence

We used the competition between the VHS and Beta videotaping formats to illustrate the possible types of path dependence claims. 19 We now turn to the actual history of this case, a history that is significant for several reasons. It is a case that is commonly cited to illustrate the claim that theoretical models of path dependence have empirical content.

Further, it incorporates structural features found in some of the models discussed here, in particular economies to scale and ownership. Finally the actual history arguably reverses the claim that an inferior format (VHS) dominated as a result of technological interrelatedness and economies to scale.

The first commercially viable video recorder was publicly demonstrated in 1956 by the Ampex Corporation. These machines were sold for several years to professional broadcasters, as Ampex did not perceive a large consumer market. Eventually, Ampex concluded that transistors would replace tubes, and having no experience transistors, entered into an agreement with Sony. Sony would transistorize the videorecorder, and in return would receive the rights to use Ampex's patents for the home-use (nonprofessional) market, which Ampex was willing to cede. This relationship quickly soured, however, and Ampex found that it needed a Japanese partner to sell its recorders to the Japanese broadcast market. This time Ampex entered a partnership with Toshiba. Other Japanese electronics producers then purchased the use of Ampex's patents for their manufacture of video recorders. Eventually various incompatible models of videorecorders coexisted in the marketplace, but none of these early machines proved successful in the home-use market.

In 1969 Sony developed a cartridge based system, the U-matic, for the home-use market. Since Matsushita, JVC (an independent subsidiary of Matsushita), Toshiba and Hitachi all had such products in the works, Sony sought to bring in some partners to share the format so as to better establish its format as a standard. Thus Matsushita and JVC were invited to join Sony, and when Sony agreed to make a few changes to the machine, the three companies each agreed to produce machines based on the U-matic specification (although Sony got the bulk of the sales by bringing the machines to market first). These three companies also agreed to share technology and patents. Production of the U-matics began in 1971 but high costs and excessive bulk led to its failure in the home-use market, although educational and industrial users provided a sustainable customer base.

Attempts to break into the home market continued. In 1972 an American company came out with a product called "Cartrivision", which did many of the things that a Betamax was to later do (although it traded off picture quality for a longer playing time). This machine was sold with a library of prerecorded programs. Cartrivision failed when several technical problems arose, including the decomposition of the prerecorded tapes in a warehouse, leaving the investors unable to overcome negative publicity. Phillips produced a home recorder in 1972, but it never achieved much success. Sanyo and Toshiba joined forces to launch a machine known as the V-Cord, which did poorly in the home-use market. Matsushita produced a machine called the AutoVision, which proved to be a dismal failure. Matsushita's management attributed this failure to the AutoVision's thirty minute tape capacity. Another Matsushita subsidiary, Kotobuki, introduced the VX-100 to the home-use market. Sony began selling the Betamax in April of 1975, with a tape capacity of one hour. JVC was also working on a machine, known as the Video Home System, or VHS.

As it had done earlier with the U-matic, Sony sought to make Betamax the standard that would cut through the clutter of competing formats. Prior to introducing the Betamax to the market, it once again offered its format to Matsushita and JVC. Sony provided technical details of the Betamax, including an advance in azimuth recording that helped eliminate the problem of crosstalk. After lengthy discussions, dragging on over a year, the three finally agreed to have a meeting where the Betamax, VHS and VX machines would be compared. This meeting took place in April of 1976 (a year after Sony had put the Betamax on the market). Lardner describes the meeting as follows:

The first item on the agenda was the simultaneous playing, through all three [machines], of a "Sesame Street" type of children's program.... The Sony contingent's eyes were on the JVC machine... What they saw was a considerably smaller machine than the Betamax... Mechanically, too, VHS had a notable distinction: the use of a loading system called M-loading... The basic concept had been tried in some of the early U-matic prototypes... In other respects, JVC's and Sony's machines were strikingly similar. Both were two-head, helical-scanning machines using half-inch tape in a U-matic type of cassette. Both -- unlike the V-cord, The VX, and indeed all the color video recorders to date -- used azimuth recording and countered the problem of cross talk by juggling the phase of the color signal. So the Betamax and the VHS were in a class by themselves as far as tape efficiency went. The real difference between them lay in how the two companies had chosen to exploit that advantage: Sony to make the cassette paperback size, and JVC to achieve a two-hour recording capacity..... Eventually one of [the Sony men] said what all of the Sony representatives were thinking: "Its a copy of Betamax." (Lardner: 151-52).

Needless to say, this apparent usurping of the Sony technological advances by JVC created bitterness between the one-time allies, leaving Sony and Matsushita-JVC to go their separate ways.

The only real technical difference between Beta and VHS was the manner in which the tape was threaded and, more importantly, the size of the cassette. A larger cassette allowed more tape to be used, and for any given speed of tape, this implied a greater recording time. For any given recording technique, slowing the tape increases recording time, but it also decreases picture quality. Because of its larger size cassette, VHS could always have an advantageous combination of picture quality and playing time. Otherwise, the differences between Beta and VHS were fairly trivial, from a technical point of view, although both of these formats were clearly superior to many of the alternatives. Memories of the differences between Beta and VHS are likely magnified by the advertising claims of each camp, the passage of time, and possibly by the fact that Beta still survives, reincarnated as a high-end videophile device.

The different choices of cassette size were based on a different perception of consumer desires: Sony believed that a paperback sized cassette, allowing easy transportability (although limiting recording time to 1 hour), was paramount to the consumer, whereas Matsushita, responding to the failure of its "Autovision" machine, believed that a 2 hour recording time, allowing the taping of complete movies, was essential.

This difference was to prove crucial. Sony, in an attempt to solidify its dominance of the US market, which it had virtually monopolized for almost two years, allowed its Beta machines to be sold under Zenith's brand name (Zenith being one of the major US television manufacturers). To counter this move, Matsushita set up a meeting with RCA to discuss a similar arrangement. RCA had previously concluded and publicly stated that a two-hour recording time was essential for a successful home video recorder. By the time the meeting took place, however, Sony had announced a two-hour Betamax, Beta II. RCA proposed to Matsushita that it produce a machine that could record a football game, which implied a 3 hour recording time. Six weeks later Matsushita had a working four-hour machine which used the same techniques to increase recording time that Sony had used in the Beta II.

RCA began selling VHS machines in the summer of 1977 (two years after Sony's introduction of the Betamax), dubbing its machine "SelectaVision." The advertising copy was simple: "Four hours. \$1000. SelectaVision." Zenith responded by lowering the price of its Beta machine to \$996. But within months, VHS was outselling Beta in the United States. A Zenith marketing executive is quoted as saying: "The longer playing time turned out to be very important, and RCA's product was better styled."

Although Sony was able to recruit Toshiba and Sanyo to the Beta format, Matsushita was able to bring Hitachi, Sharp, and Mitsubishi into its camp. Any improvement in one format was soon followed by a similar improvement in the other format. The similarities in the two machines made it unlikely that one format would be able to deliver a technological knockout punch. Similarly, when one group lowered its price, the other soon followed. The two formats proved equally matched in almost all respects save one: VHS's longer playing times. When Beta went to two hours, VHS went to four. When Beta increased to 5 hours, VHS increased to 8. Of course, consumers wishing higher picture quality would set either machine to shorter playing times.

The market's referendum on playing time versus tape compactness was decisive and immediate. Not just in the United States, but in Europe and Japan as well. By mid 1979 VHS was outselling Beta by more than 2 to 1 in the US. By 1983 Beta's world share was down to 12 percent. By 1984 every VCR manufacturer except Sony had adopted VHS. 20

Klopfenstein (1989: 28) summarizes (our italics):

Although many held the perception that the Beta VCR produced a better picture than VHS, technical experts such as Weinstein (1984) and Prentis (1981) have concluded that this was, in fact, not the case; periodic reviews in Consumers Reports found VHS picture quality superior twice, found Beta superior once, and found no difference in a fourth review. In conclusion, the Beta format appeared to hold no advantages over VHS other than being the first on the market, and this may be a lesson for future marketers of new media products.

How then does this history address the theory and empiricism around path dependence? First, and most obviously, it contradicts the claim that the Beta format was better and that its demise constitutes evidence of the pernicious workings of "decentralized decision making" or "sensitive dependence on initial conditions." Regarding the one aspect that clearly differentiated the two formats, consumers preferred VHS.

Second, even though the differences between the two formats are small, the advantage of longer recording times was sufficient to allow VHS to overcome Beta's initial lead. There might not have been any great harm had the market stayed with Beta, since its recording time was up to five hours by the early 1980's. But consumers were not willing to wait those few extra years, and the market was supple enough to make the switch to the better path.

Third, the history illustrates the role of ownership, strategy and adopter's foresight in allowing a change in paths. The formats were each owned, and both Sony and JVC-Matsushita expended considerable effort to establish its standard, indicating that they expected to capture some of the benefits of doing so. The ability of VHS to attract partners such as RCA and Matsushita indicates the market participants' ability to recognize the large potential gains from promoting a superior standard. Although it is sometimes argued that the dominance of VHS resulted from the random association of VHS with a more aggressive licensing and pricing strategy, we have shown the pricing and promotion of the two formats to be closely matched. On the other side of the market, consumers could identify a preferred standard and predict that an adequate number of others would do the same. Not only was the switch to VHS rapid, but it was repeated in separate national markets. Thus there is no evidence that the market choice was due to blunders, unlucky promotional choices, or insufficient investment by the owners of the Beta format.

5. Path Dependence and The Role of History

Much of the reason for the influence of the literature of path dependence, particularly among economic historians, is the appeal that it makes for the importance of history. If outcomes depend critically upon insignificant and unpredictable events, rather than on underlying conditions such as endowments and technology, then an historical chronicle is elevated in importance relative to other methods of explanation. But this rationale for an interest in history is very limited. In the path dependence literature, the importance of history is related to what have been called the non-ergodic properties of the economy. Arthur uses this terminology, defining processes to be "non-ergodic" if outcomes are affected by the sequence of events. Regarding history Arthur notes:

The argument of this paper suggests that the interpretation of economic history should be different in different returns regimes. Under constant and diminishing returns, the evolution of the market reflects only a priori endowments, preferences, and transformation possibilities; small events cannot sway the outcome. But while this is comforting, it reduces history to the status of mere carrier -- the deliverer of the inevitable. Under increasing returns, by contrast, many outcomes are possible. Insignificant circumstances become magnified by positive feedbacks to "tip" the system

into the actual outcome "selected." The small events of history become important. (1989: 127)

In this analysis, history is important only because the sequence of events determines current values. If the sequence does not affect the end result, there is little place for history; it is a "mere carrier -- the deliverer of the inevitable."

But surely history should be of interest even when economic processes are ergodic -- even when there are decreasing returns. While it may be useful to model supply-and-demand equilibria, no one actually believes that exogenous changes do not occur. There are important and frequent external shocks to the economy, and, at any moment, unknown parameters (such as the importance to consumers of video recorder taping time). So a knowledge of some initial endowment alone could never tell us very much about the eventual path of real economies over time. In addition, the endowment of one generation is the bequest of another, and there is value in learning what actions previous generations took that increased or decreased their wealth.

These views of the role of history constitute rival paradigms. One holds that efficiency explanations are important and that economic history, at least, is the search for purpose in past actions. We find, where we can, explanations of events that are based on purposeful behavior: Technology responds to scarcities, technique responds to price, and so on. The other holds that history is important only to the extent that, for one reason or another, agents do not successfully optimize. History then is the tool to understand what rationality and efficiency do not explain, that is, the random sequence of insignificant events that are not addressable by economic theory. We leave it to the reader to decide which paradigm promises greater returns to the study of history.

6. Conclusion

Anyone would be willing to acknowledge that some of the things people do have durable consequences -- which, by definition, is also an acknowledgment of first-degree and second-degree path dependence. Further, it is difficult to deny that if immeasurably small things that we do today lead inexorably to enormous differences in the world we receive tomorrow, our futures are unpredictable and potentially inefficient. The special importance of path dependence, however, is associated with third-degree claims -- that is, inherited inefficiencies that purportedly are, or were, remediable. Remediable inefficiency, if it occurred, would be a significant lapse and a demonstrated instance would be an interesting finding worthy of analysis. A pattern of such instances would be of great importance. However, lesser forms of path dependence should not be mistakenly classified as remediable.

Our assertion of the rarity of third-degree path dependency is not simply the result of some Panglossian mysticism. Rather it follows from a rather worldly consideration. Where there is a knowable and feasible improvement from moving onto a better path, those who will benefit from the improvement, and who know it, will be willing to pay to bring the improvement about. Where simple spot market transactions are insufficient to bring these improvements about, institutional or strategic innovation seems a likely

response, especially if the improvement is important enough that the innovator is likely to be well paid.

The logic underlying path dependence is seductive but incomplete. Although these simple numerical and algebraic examples appear both logically sound and structurally uncontroversial, these examples actually imbed severe restrictions. The seeming inevitability of third-degree path dependence is overturned, in instances shown here, by rather ordinary and conventional means, as prosaic as the market for land. Given that the theoretical claim that can be made for path dependency should be understood as only a demonstration of possibility, the case for path dependency becomes an empirical one.

The empirical case is on no firmer footing than the theoretical case. To date, convincing documentation of cases in which market activity sustains remediable error remains absent. As we have developed here, the oft cited case of videotaping formats is not a demonstration of third-degree path dependence. Perhaps the best evidence of the empirical shortcomings of path dependence is the continued use of the story of the QWERTY keyboard as support for theoretical models, in spite of our 1990 demonstration that the actual history does not support a claim of deleterious path dependency. This purported example of a market failure has so much appeal that a theoretical literature continues to define and support itself around it. That QWERTY remains the paradigmatic case for path dependency surely says something important about the empirical content of this theory.

Given all this, path dependency would certainly seem to be a poor candidate as the distinguishing implication of a "new economics." But still, there may be something to be learned from what does not happen. The theoretical exercises that are offered by Brian Arthur and others suggest the inevitability of failure under simple assumptions. That these models are not borne out empirically suggests the importance of communication, planning, property, and other market institutions that are absent from these models but which are essential elements in any explanation of the actual workings of the economy.

Footnotes

1 It has been claimed, for example, that historical accidents may have left us with the wrong types of automobiles, video recorders, nuclear power plants, and typewriter keyboards. These examples are cited by many authors in this literature as well as the literatures on standards (Farrell and Saloner), network externalities (Katz and Shapiro), game theory (Dixit and Nalebuff), and organizational behavior (ecology). See Zerbe (1992) and Levinson and Coleman (1992), in addition to our 1990, 1994a, 1994b, and 1995 papers for alternative views to much of this literature.

2 For example, it plays a role in the recent exchange between Bowles and Gintis (1993) and Williamson (1993) over the value of the neoclassical paradigm.

3 Williamson (1993b, p. 140) offers the term "remediability" to describe the condition that such feasible alternatives exist, and urges remediability as the appropriate standard for public policy discussion. Similar positions have been argued by Demsetz, Coase,

Calebresi and Dahlman, among others. In the framework that these authors have advocated, market failure is not demonstrated unless a specific policy recommendation can be shown in which the benefits exceed the costs, including all of the administrative costs of the policy. We note that this is not a Panglossian view of the world-- the world need not be optimal -- but it does alter the burden of proof. Claims of market imperfections cannot be established upon the theoretical possibility of an improved allocation, but require a feasible alternative for a particular case.

4 Further, some of the most prominent examples in this literature feature specific claims of inefficiency. For example, listen to Paul David: "The accretion of technological innovations inherited from the past therefore cannot legitimately be presumed to constitute socially optimal solutions provided for us -- either by heroic enterprises or herds of rational managers operating in efficient markets." (1992, p. 137)

5 These are the dynamic versions of issues raised above, see note 3.

6 For a general statement see Rasmussen p. 44.

7 In the physical sciences, hysteresis means that the equilibrium "remembers" all disturbances. Explicit applications in economics have been directed mostly at explaining persistent unemployment, especially regarding recent European experience. A difference is that the hysteresis literature is concerned with the possibility that shocks echo in the data, perhaps permanently whereas the economic literature on path dependence has focused on discrete choices where outcomes are discretely separated. For discussion, see Blanchard and Summers, the Mini symposium in the journal of Post Keynesian Economics, especially the paper by Katzner, and the Symposium in Empirical Economics, especially the overview paper by Franz.

8 Adopted from Encyclopedic Dictionary of Mathematics, p. 1287.

9 In the discussion that follows, we use the Hicks-Kaldor standard as an efficiency norm.

10 Second-degree path dependence also is being invoked in the "what if" type of regrets, perhaps better termed "hypothetical path dependence", that one finds in this literature. The key element here is that knowledge is limited but could have been increased through the use of resources. For example, it is sometimes claimed (Arthur, 1990) that it might have been wiser to have used electric cars at the turn of the century, and not the gasoline-powered internal combustion engine. The fact that our current state of knowledge indicates that electric-powered automobiles are less efficient is considered irrelevant, since if we had been producing electric cars since the turn of the century our knowledge about batteries would presumably be advanced far beyond what it currently is, and electric cars under that scenario might be more efficient than are the internal combustion automobiles of today. Of course, it is impossible to refute this claim since it rests on knowing the unknowable: What would we know today if we had invested resources in generating knowledge other than that in which we did invest? Hypothetical path dependence cannot provide real examples, nor can it be disproved.

11 Williamson (1994) notes the possibility that redistributive arrangements may be deliberately constructed to be costly to alter in order to bind parties to political bargains. Interestingly, the resulting inflexibility may be recognized as an unavoidable cost, given the political decision to redistribute wealth.

12 One question that leaps immediately to mind is who it is that possesses this information. We discuss the role of information below.

13 The concept of a superior technology is not unambiguous. The advantage of a technology cannot be defined independently of the state of knowledge, which itself depends on the path taken. Thus superiority can not be defined exogenous to the trials of the technology.

14 We should note that both Gould and Mokyr warn of misapplication of biological evolution to social systems. Both note that in social systems there is the possibility of returning to once discarded solutions.

15 Actually, Arthur states that this example does not exhibit any "non-ergodicity," meaning that it is not path dependent in the sense that small difference in historical sequences of events do not play a role in the final equilibrium. In this example the end result is the same no matter the order of initial participants. But it illustrates "lock-in" very well.

16 Arthur has informed us in correspondence that he intended that the payoffs be based only on the adopter's position in the table, not the eventual number of adopters. We note, however, Arthur's inconsistent usage in the text of his article since under his intended assumption, option B is not preferred until the fifty-first adopter, not the thirty mentioned in his text.

17 These calculations assume that the table represents the steps in a step function, so that entrants to A from one to ten get ten, entrants from eleven to twenty get eleven etc.

18 Though see Kitch for a related argument.

19 This history draws on Lardner (1987), chapters 3, 4, and 10.

20 Contrast this version with Arthur's 1990 history: "The history of the videocassette recorder furnishes a simple example of positive feedback. The VCR market started out with two competing formats selling at about the same price: VHS and Beta.Both systems were introduced at about the same time and so began with roughly equal market shares; those shares fluctuated early on because of external circumstance, "luck" and corporate maneuvering. Increasing returns on early gains eventually tilted the competition toward VHS: it accumulated enough of an advantage to take virtually the entire VCR market. Yet it would have been impossible at the outset of the competition to say which system would win, which of the two possible equilibria would be selected.

Furthermore, if the claim that Beta was technically superior is true, then the market's choice did not represent the best outcome." (p. 92)

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Consumers Aren't Stuck in Product Rut, Economist Finds

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Consumers Aren't Stuck in Product Rut, Economist Finds

FOR IMMEDIATE RELEASE

Are consumers zombies, blindly accepting whatever products marketers choose to sell them, or do producers respond to the desires of consumers and give them what they want?

This economic debate is heating up with the popularization of the "path dependence" hypothesis -- the idea that consumers get stuck in a rut and keep using one product even when there is a better alternative, because they're the victims of historical accidents.

But the fact is that consumers make conscious choices, and the marketplace almost always responds, says Dr. Steve Margolis, an economics professor at North Carolina State University.

And Margolis is worried that if path dependence theory becomes widely accepted, with the government using it as a basis for intervening in markets to "save" consumers from being locked into inferior technology, there will be far-reaching, serious economic results.

Respected publications, from academic journals to Fortune and The New York Times, have published articles touting the dangers of path dependence. Lawyers last year filed a brief with the U.S. Justice Department that claims that Microsoft Corporation's "control of information transmission threatens our society."

Margolis, whose curiosity about path dependence prompted him to begin studying the concept in 1988, has become convinced of its fallacy. "Both consumers and producers have a lot at stake in making these choices correctly," he says.

The stories of typewriter keyboards and of VHS vs. Beta videotapes have been cited repeatedly by path dependence theorists as classic examples of path dependence and its resulting market failure. But as Margolis has discovered, the stories are more like fables: inflated, inaccurate, second-hand tales with very little basis in fact.

This is a nutshell version of one: the typewriter's inventor arranged the keyboard to slow down typists, so the hammers would not jam as often. By the 1880s, public demonstrations of typing speed were held for entertainment. At a contest in Cincinnati, Francis McGurrin had memorized the Remington "QWERTY" keyboard he used, while Louis Taub used a hunt-and-peck technique on a rival machine with a different keyboard arrangement. McGurrin won easily.

Because of this contest, typists and computer users to this day are stuck with "QWERTY" (so called after the letters on the top row) keyboards that are inefficiently arranged to solve a problem that has long since ceased to exist, according to path dependence theorists.

"What's worse, according to supporters of this theory, is that a much better keyboard was designed in 1936 by August Dvorak, but path dependence kept it from being widely adopted," Margolis says. "According to the popular story, QWERTY 'got there first' so it was established as the standard. Everybody used it because everybody else was using it, even after the 'superior' Dvorak keyboard came along."

But there are several major flaws with this story, something Margolis found out as he and his co-researcher, Stan Liebowitz of the University of Texas at Dallas, delved into the historical literature, including original sources such as newspaper stories from the 1880s.

- * The QWERTY arrangement was not designed to slow down typists, but to keep keys that were often struck in succession as far apart as possible. Tests have shown QWERTY to be an efficient arrangement for typing and one that is ergonomically sound.

- * There were many typing contests in the 1880s involving several competing keyboard arrangements, and QWERTY did not always win. The contest results were published in major newspapers. Consumers chose QWERTY because they preferred it, not because they were "locked into" it by one contest.

- * The Dvorak keyboard isn't better than QWERTY. The study that is supposed to show the superiority of Dvorak was conducted by none other than Navy Lt. Cmdr. August Dvorak himself. The study, which Margolis and Liebowitz finally located in a private collection, was not an official Navy study. The results that it claims are so extreme that, as Margolis points out, if they were accurate, many businesses surely would have adopted the Dvorak keyboard.

"The study claims that retraining typists on Dvorak pays for itself in 10 days and yields an annual return of more than 2,000 percent," Margolis says. "With such an astonishing return, I have to wonder how many path dependence researchers have made the switch themselves."

Another story, about the mid-1980s struggle for dominance between Beta and VHS video systems, also is cited as an example of path dependence. But Margolis' research shows, once again, that the marketplace responded to consumer desires. Home users wanted tapes that were long enough to record movies, while commercial users valued editing capabilities. VHS won the home market, and Beta won the commercial market.

"The supporters of path dependence are wrong," Margolis says. "The commercial world is much richer than the one modeled in this theory. There are all kinds of things happening alongside the 'path,' and consumers have many sources of information on which to base their decisions. The fact is that markets respond to consumers."

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<http://www.cato.org/pubs/regulation/reg18n3b.html>

Stan Liebowitz and Stephen E. Margolis:

"Policy and Path Dependence:

From QWERTY to Windows 95"

One avant-garde excuse for retaining federal powers to intervene in the economy is that certain technologies that get on the market first might not be the best, but they will, the argument goes, have such a lead over latecomers that better products and approaches will never have a chance. Now, many might think immediately of VHS beating out first-on-the-market Beta VCRs, the latter being considered superior in quality. But in Washington's attention-deficit discussions, a more focused analysis is often required.

The order of letters on a typewriter keyboard, known as "QWERTY" after the first six letters—the keyboard arrangement being tapped by my fingertips at this very moment—is said by regulation's supporters to be inferior to another system, called Dvorak, that was not able to break into the market. The QWERTY example is used by those who would put restrictions on, for example, Microsoft's Windows 95 software, which supposedly gives it too great a lead over competitors. (Never mind that IBM personal computers with Microsoft software beat first-in, and in many ways superior, Apple down to a 15 percent share of the market.)

Stan Liebowitz and Stephen E. Margolis show that the typewriter example is, in fact, just plain wrong. No tests ever established Dvorak's superiority. No copy of a Navy study sometimes quoted in support of Dvorak's superiority can even be found. But what is known is that the study was done under the supervision of August Dvorak, the system's inventor and hardly an impartial judge. Finally, the authors provide evidence to suggest that the QWERTY keyboard is less stressful on the hands than alternative arrangements.

<http://www.jewishworldreview.com/cols/shlaes030701.asp>

Trampling on the theory of path dependence

Microsoft's judges may decide that consumer approval rather than illegal tactics led to the company's power

<http://www.jewishworldreview.com> -- MICROSOFT looks as if it may evade the dismemberment ordered in the finding sent up by Judge Thomas Penfield Jackson. Not only have federal appeals court judges shown some sympathy for the company's case, but the Bush administration may also revise antitrust policy and offer it a settlement. Microsoft stock's recent rise reflects these new prospects.

But what about the underlying theory that convinced Judge Jackson that Microsoft needed dismantling in the first place? He leaned repeatedly towards an economic idea known as path dependence.

The position that the appeals court or the Justice Department take on this issue will do much to determine Microsoft's fate. Path dependence is also a key part of modern monopoly theory generally, so has a bearing on other antitrust cases.

So what precisely is it? Path dependence says that a company may gain an overwhelming advantage in a market if it manages to establish an industry standard before anyone else. That standard then becomes so powerful that it becomes a barrier to better challengers. The company, in short, creates an impregnable monopoly.

The textbook example here has long been the qwerty keyboard. Its critics argue that it is less efficient than other key arrangements. Their position is that it has dominated for a century merely because one of the first manufacturers of the manual typewriter, E. Remington, adopted it early on, ensuring that it would become the standard. Path dependence emphasises, sometimes close to exclusively, the competitor as victim. Consumers are part of path dependence theory too - but only indirectly; they lose because the competitor does.

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Bunkum, say two professors of economics, Stan J. Liebowitz of the University of Texas at Dallas and Stephen E. Margolis of North Carolina State in *Winners, Losers & Microsoft : Competition and Antitrust in High Technology* (PAPERBACK). Markets are meritocracies where good products win, be they mouse traps or operating systems. An item's success is due more to its quality than to any industrial predation.

Start with the qwerty keyboard. The professors argue that qwerty was hardly the competition-free gladiator that received wisdom makes out. It turns out that there were 51 rivals to Remington's qwerty at the outset. Remington's qwerty prevailed not because of

market share alone but also because qwerty typists won at much-publicised typing contests.

Then there is the showcase argument against qwerty: DSK, a keyboard arrangement patented in 1936 by ergonomics expert August Dvorak. Dvorak tested DSK in Chicago schools and found data indicating its superiority. In the second world war, DSK was pitted against qwerty at the US Navy. Recruits who had once performed at a measly 32 words a minute speeded up to a masterly 56. Yet the old qwerty standard still prevailed.

Messrs Liebowitz and Margolis have unearthed evidence to show that DSK's superiority is something of a fable. For one thing, as it turns out, the co-author of the landmark Navy study was Dvorak himself. And later studies failed to replicate the pro-Dvorak evidence.

Another supposed paradigm of path dependence is the famous Beta-VHS war. Sony's Beta, the argument runs, was a good product. But through sheer market aggression, RCA, the US distributors of VHS, managed to make VHS the US standard and so obtained an enduring monopoly.

But this, the professors note, is an incomplete account. While the technology of the two products was identical, Sony took a fateful step in crafting its cassettes. It believed portability would be the most attractive feature for the cassette. It made its product smaller - but with a playing time of only one hour, in contrast to VHS, which could handle full-length films. Filmgoers, as it turned out, became big video customers. VHS won.

In the Microsoft case, the company's advantage is Windows' superiority and not Microsoft's scheming. Messrs Liebowitz and Margolis criticise Judge Jackson's view that Microsoft did social damage by bundling its browser, Internet Explorer, in the Windows package. This may have hurt Netscape, a competitor, as the latter loudly claimed. But there is little evidence that it hurt the consumer, at least not in the long run.

The authors offer a telling example from an older industry giant, car manufacture. In the old days, US carmakers sold vehicles without the rustproofing necessary in bitter climates. Cautious buyers then took their new purchases to rustproofing specialists for treatment. Later, carmakers incorporated rustproofing into their own product.

This may have hurt America's big rustproofing company, Ziebart. It even disrupted car owner habits temporarily. But car owners in the long run were not unhappy to receive a road-ready product. Or, as the authors put it, "a rule that compels a look at consumer perception as though frozen in time will be harmful".

Given the failings of path dependence, why its prevalence as a way of looking at the world? Messrs Margolis and Liebowitz argue that path dependence survives because it is an argument that suits some of the biggest players in the global antitrust drama: competitors. Jack Welch of General Electric complained last week in a different context

(the European Commission's review of GE's plan to merge with Honeywell), of regulators being more concerned with competitors than consumers.

But while competitors have much to lose in battles against strong companies, it is not necessarily true that their defeat is also the consumer's. That is a valuable warning at a time when vigorous antitrust action has become the norm.

<<http://www.jewishworldreview.com/weeglobe.GIF>>

<http://www.wired.com/news/politics/0,1283,21703,00.html>

Book Pulls MS Off the Hook

by Declan McCullagh

5:30 p.m. Sep. 10, 1999 PDT

Anyone who's followed the US v. Microsoft antitrust trial or heard the angry accusations from rival execs at computer conferences knows the basics of the argument against the world's mightiest software company.

It goes something like this: By leveraging its Windows monopoly, Microsoft dominates other software areas, such as browsers, word processors, and spreadsheets. Network effects take over, consumers get the shaft, and Bill Gates' net worth zooms up another 10 billion dollars, give or take a few decimal points.

A new book by two free-market economists, Stan Liebowitz and Stephen Margolis, takes well-argued and careful aim at that idea.

Winners, Losers, and Microsoft (The Independent Institute, \$29.95) features what appears to be the first systematic look at the real-world history of the software industry -- and the results are sure to give Department of Justice (DOJ) trial attorneys the heebie-jeebies.

The duo's conclusion? "When Microsoft moved from a low- to a high-market share, its products were always of a higher quality than the market leader's. When its products were not superior, it did not make inroads against the market leader."

This is the book that should, if justice prevails, become as influential in today's antitrust debates as Robert Bork's *The Antitrust Paradox* did two decades ago.

Here's some free advice to Microsoft's trial attorneys: Introduce all 287 pages as a defense exhibit. If you don't, you're ignoring some of the best evidence that your side has to offer.

Liebowitz, a professor of economics at the University of Texas at Dallas, and Margolis, the head of the economics department at North Carolina State University, devote most of the book to refuting the idea of "network effects."

That theory, which has recently found support among mainstream economists and Justice Department attorneys, predicts that consumers can end up buying the same type of product that everyone else has purchased -- even if it isn't the best -- for compatibility's sake.

The usual example is QWERTY. Supposedly, in 1936, education prof August Dvorak created a keyboard of the same name (with vowels on the home row) that was speedier. But everyone was already using QWERTY, network effects took over, and the unhappy end result is that every one of us wastes countless hours each year typing on a slothful, awkward keyboard.

Many folks in the computer industry seem to agree with this view of history.

Apple's Steve Jobs has mentioned it in speeches. The Wall Street Journal cited it uncritically in a front-page article, saying network effects are "why most people use a keyboard that begins clumsily with the letters QWERTY." So have leading economic textbooks.

Not so fast, say Liebowitz and Margolis, who have emerged as two of economic history's most prominent myth-debunkers. They've taken a hard look at what actually happened, and show in Chapter 2 that "support for the claim that Dvorak is a better keyboard is both scant and suspect."

There was plenty of competition between different keyboards at the time, according to New York Times articles they found, and Dvorak himself was the author of a slipshod Navy study that economists who like "network effects" arguments have cited without reading. In later chapters, the book also debunks the Beta-is-better-than-VHS myth through highlighting articles such as side-by-side comparisons by Consumer Reports.

In its antitrust case, the US government relies on "network effects" theories.

Its top economic expert, Franklin Fisher, claims that the "dominance of Microsoft's Windows 9X operating System ... is protected, among other things ... which are sometimes referred to as network effects."

The Microsoft antitrust suit filed by some state attorneys general makes the identical claim, as have briefs written by Microsoft arch-enemy Gary Reback.

But do network effects really apply here? No, the book argues. Instead, software markets seem to feature "serial monopolies," such as in spreadsheets, where VisiCalc gave way to Lotus 1-2-3 which in turn was succeeded by Microsoft Excel. But that doesn't mean that these pseudo-monopolies hurt consumers -- far from it, since users will switch en masse when a distinctly better product comes along.

Liebowitz and Margolis built a database of product reviews and market share percentages to compare MS products with competitors'. They conclude that MS has been unsuccessful "except when their products are better than the opposition."

They had to resort to an attempt to buy [Intuit]; they have barely dented America Online with the much ballyhooed Microsoft Network; and they only began to erode Netscape's near-monopoly when their own browser came up to snuff."

It's true that the authors are free-market proponents who might reasonably be expected to take a stand against the DOJ's expansive view of antitrust law.

They occasionally get some technical details wrong, such as confusing the magneto-optical drive on the original NeXT computer with a CD-ROM.

But the book remains an invaluable addition to the bookshelf of anyone interested in the Microsoft trial and future high-tech antitrust cases.

To date, much of the bitterness has been over theory. Liebowitz and Margolis inject facts. They may be incomplete, but this book is the best compilation that anyone's offered so far, and now the burden is on Microsoft's adversaries to refute it.