Clio and the Economics of QWERTY

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Cicero demands of historians, first, that we tell true stories. I intend fully to perform my duty on this occasion, by giving you a homely piece of narrative economic history in which "one damn thing follows another." The main point of the story will become plain enough: it is sometimes not possible to uncover the logic (or illogic) of the world around us except by understanding how it got that way. A *path-dependent* sequence of economic changes is one of which important influences upon the eventual outcome can be exerted by temporally remote events, including happenings dominated by chance elements rather than systematic forces. Stochastic processes like that do not converge automatically to a fixed-point distribution of outcomes, and are called *non-ergodic*. In such circumstances "historical accidents" can neither be ignored, nor neatly quarantined for the purpose of economic analysis; the dynamic process itself takes on an *essentially historical* character. Standing alone, my story will be simply illustrative and does not establish how much of the world works this way. That is an open empirical issue and I would be presumptuous to claim to have settled it, or to instruct you in what to do about it. Let us just hope the tale proves mildly diverting for those waiting to be told if and why the study of economic history is a necessity in the making of economists.

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I. The Story of QWERTY

Why does the topmost row of letters on your personal computer keyboard spell out QWERTYUIOP, rather than something else? We know that nothing in the engineering of computer terminals requires the awkward keyboard layout known today as "QWERTY," and we all are old enough to remember that QWERTY somehow has been handed down to us from the Age of Typewriters. Clearly nobody has been persuaded by the exhortations to discard QWERTY, which apostles of DSK (the Dvorak Simplified Keyboard) were issuing in trade publications such as *Computers and Automation* during the early 1970's. Why not? Devotees of the keyboard arrangement patented in 1932 by August Dvorak and W. L. Dealey have long held most of the world's records for speed typing. Moreover, during the 1940's U.S. Navy experiments had shown that the increased efficiency obtained with DSK would amortize the cost of retraining a group of typists within the first ten days of their subsequent full-time employment. Dvorak's death in 1975 released him from forty years of frustration with the world's stubborn rejection of his contribution; it came too soon for him to be solaced by the Apple IIC computer's built-in switch, which instantly converts its keyboard from QWERTY to virtual DSK, or to be further aggravated by doubts that the switch would not often be flicked.

If as Apple advertising copy now says, DSK "lets you type 20–40% faster," why did this superior design meet essentially the same rejection as the previous seven improvements on the QWERTY typewriter keyboard that were patented in the United States and Britain during the years 1909–24? Was it the result of customary, nonrational behavior by countless individuals socialized to carry on an antiquated technological tradition? Or, as Dvorak himself once suggested, had there been a conspiracy among the members of the typewriter oligopoly to suppress an invention which they feared would so increase typewriter efficiency as ultimately to curtail the demand for their products? Or perhaps we should turn instead to the other popular "Devil Theory," and ask if political regulation and interference with the workings of a "free market" has been the cause of inefficient keyboard regimentation? Maybe it's all to be blamed on the public school system, like everything else that's awry?

You can already sense that these will not be the most promising lines along which to search for an economic understanding of QWERTY's present dominance. The agents engaged in production and purchase decisions in today's keyboard market are not the prisoners of custom, conspiracy, or state control. But while they are, as we now say, perfectly "free to choose," their behavior, nevertheless, is held fast in the grip of events long forgotten and shaped by circumstances in which neither they nor their interests figured. Like the great men of whom Tolstoy wrote in *War and Peace*, "(e) very action of theirs, that seems to them an act of their own free will, is in an historical sense not free at all, but in bondage to the whole course of previous history..." (Bk. IX, ch. 1).

This is a short story, however. So it begins only little more than a century ago, with the fifty-second man to invent the typewriter. Christopher Latham Sholes was a Milwaukee, Wisconsin printer by trade, and a mechanical tinkerer by inclination. Helped by his friends, Carlos Glidden and Samuel W. Soule, he had built a primitive writing machine for which a patent application was filed in October 1867. Many defects in the working of Sholes' "Type Writer" stood in the way of its immediate commercial introduction. Because the printing point was located underneath the paper carriage, it was quite invisible to the operator. "Non-visibility" remained an unfortunate feature of this and other up-stroke machines long after the flat paper carriage of the original design had been supplanted by arrangements closely resembling the modern continuous roller-platen. Consequently, the tendency of the typebars to clash and jam if struck in rapid succession was a particularly serious defect. When a typebar stuck at or near the printing point, every succeeding stroke merely hammered the same impression onto the paper, resulting in a string of repeated letters that would be discovered only when the typist bothered to raise the carriage to inspect what had been printed.

Urged onward by the bullying optimism of James Densmore, the promoter-venture capitalist whom he had taken into the partnership in 1867, Sholes struggled for the next six years to perfect "the machine." From the inventor's trial-and-error rearrangements of the original model's alphabetical key ordering, in an effort to reduce the frequency of typebar clashes, there emerged a four-row, upper case keyboard approaching the modern QWERTY standard. In March 1873, Densmore succeeded in placing the manufacturing rights for the substantially transformed Sholes-Glidden "Type Writer" with E. Remington and Sons, the famous arms makers. Within the next few months QWERTY's evolution was virtually completed by Remington's mechanics. Their many modifications included some fine-tuning of the keyboard design in the course of which the "*R*" wound up in the place previously allotted to the period mark "." Thus were assembled into one row all the letters which a salesman would need to impress customers, by rapidly pecking out the brand name: TYPE WRITER

Despite this sales gimmick, the early commercial fortunes of the machine, with which chance had linked QWERTY's destiny remained terrifyingly precarious. The economic downturn of the 1870's was not the best of times in which to launch a novel piece of office equipment costing $125, and by 1878, when Remington brought out its Improved Model Two (equipped with carriage shift key), the whole enterprise was teetering on the edge of bankruptcy. Consequently, even though sales began to pick up pace with the lifting of the depression and annual typewriter production climbed to 1200 units in 1881, the market position which QWERTY had acquired during the course of its early career was far from deeply entrenched; the entire stock of QWERTYembodying machines in the United States could not have much exceeded 5000 when the decade of the 1880's opened.

Nor was its future much protected by any compelling technological necessities. For, there were ways to make a typewriter without the up-stroke typebar mechanism that had called forth the QWERTY adaptation, and rival designs were appearing on the American scene. Not only were there typebar machines with "down-stroke" and "front-stroke" actions that afforded a visible printing point; the problem of typebar clashes could be circumvented by dispensing with typebars entirely, as young Thomas Edison had done in his 1872 patent for an electric print-wheel device which later became the basis for teletype machines. Lucien Stephen Crandall, the inventor of the second typewriter to reach the American market (in 1879) arranged the type on a cylindrical sleeve: the sleeve was made to revolve to the required letter and come down onto the printing-point, locking in place for correct alignment. (So much for the "revolutionary" character of the IBM 72/82's "golf ball" design.) Freed from the legacy of typebars, commercially successful typewriters such as the Hammond and the Blickensderfer first sported a keyboard arrangement which was more sensible than QWERTY. Then so-called "Ideal" keyboard placed the sequence DHIATENSOR in the home row, these being ten letters with which one may compose over 70 percent of the words in the English language.

The typewriter boom beginning in the 1880's thus witnessed a rapid proliferation of competitive designs, manufacturing companies, and keyboard arrangements rivalling the Sholes-Remington QWERTY. Yet, by the middle of the next decade, just when it had become evident that any micro-technological rationale for QWERTY's dominance was being removed by the progress of typewriter engineering, the U.S. industry was rapidly moving towards the standard of an upright front-stroke machine with a four-row QWERTY keyboard that was referred to as "the Universal." During the period 1895–1905, the main producers of non-typebar machines fell into line by offering "the Universal" as an option in place of the Ideal keyboard.

II. Basic QWERTY-Nomics

To understand what had happened in the fateful interval of the 1890's, the economist must attend to the fact that typewriters were beginning to take their place as an element of a larger, rather complex system of production that was technically interrelated. In addition to the manufacturers and buyers of typewriting machines, this system involved typewriter operators and the variety of organizations (both private and public) that undertook to train people in such skills. Still more critical to the outcome was the fact that, in contrast to the hardware subsystems of which QWERTY or other keyboards were a part, the larger system of production was nobody's design. Rather like the proverbial Topsy, and much else in the history of economies besides, it "jes' growed."

The advent of "touch" typing, a distinct advance over the four-finger hunt-and-peck method, came late in the 1880's and was critical, because this innovation was from its inception adapted to the Remington's QWERTY keyboard. Touch typing gave rise to three features of the evolving production system which were crucially important in causing QWERTY to become "locked in" as the dominant keyboard arrangement. These features were *technical interrelatedness*, *economies of scale*, and *quasi-irreversibility* of investment. They constitute the basic ingredients of what might be called QWERTY-nomics.

Technical interrelatedness, or the need for system compatibility between keyboard "hardware" and the "software" represented by the touch typist's memory of a particular arrangement of the keys, meant that the expected present value of a typewriter as an instrument of production was dependent upon the availability of compatible software created by typists' decisions as to the kind of keyboard they should learn. Prior to the growth of the personal market for typewriters, the purchasers of the hardware typically were business firms and therefore distinct from the owners of typing skills. Few incentives existed at the time, or later, for any one business to invest in providing its employees with a form of general human capital which so readily could be taken elsewhere. (Notice that it was the wartime U.S. Navy, not your typical employer, that undertook the experiment of retraining typists on the Dvorak keyboard.) Nevertheless the purchase by a potential employer of a QWERTY keyboard conveyed a positive pecuniary externality to compatibly trained touch typists. To the degree to which this increased the likelihood that subsequent typists would choose to learn QWERTY, in preference to another method for which the stock of compatible hardware would not be so large, the overall user costs of a typewriting system based upon QWERTY (or any specific keyboard) would tend to *decrease* as it gained in acceptance relative to other systems. Essentially symmetrical conditions obtained in the market for instruction in touch typing.

These decreasing cost conditions—or *system scale economies*—had a number of consequences, among which undoubtedly the most important was the tendency for the process of intersystem competition to lead towards de facto standardization through the predominance of a single keyboard design. For analytical purposes, the matter can be simplified in the following way: suppose that buyers of typewriters uniformly were without inherent preferences concerning keyboards, and cared only about how the stock of touch typists was distributed among alternative specific keyboard styles. Suppose typists, on the other hand, were heterogeneous in their preferences for learning QWERTY-based "touch," as opposed to other methods, but attentive also to the way the stock of machines was distributed according to keyboard styles. Then imagine the members of this heterogenous population deciding in random order what kind of typing training to acquire. It may be seen that, with unbounded decreasing costs of selection, each stochastic decision in favor of QWERTY would raise the probability (but not guarantee) that the next selector would favor QWERTY. From the viewpoint of the formal theory of stochastic processes, what we are looking at now is equivalent to a generalized "Polya urn scheme." In a simple scheme of that kind, an urn containing balls of various colors is sampled with replacement, and every drawing of a ball of a specified color results in a second ball of the same color being returned to the urn; the probabilities that balls of specified colors will be added are therefore increasing (linear) functions of the proportions in which the respective colors are represented within the urn. A recent theorem due to W. Brian Arthur et al. (1983; 1985) allows us to say that when a generalized form of such a process (characterized by unbounded increasing returns) is extended indefinitely, the proportional share of one of the colors will, with probability one, converge to unity.

There may be many eligible candidates for supremacy, and from an *ex ante* vantage point we cannot say with corresponding certainty which among the contending colors —or rival keyboard arrangements—will be the one to gain eventual dominance. That part of the story is likely to be governed by "historical accidents," which is to say, by the particular sequencing of choices made close to the beginning of the process. It is there that essentially random, transient factors are most likely to exert great leverage, as has been shown neatly by Arthur's (1983) model of the dynamics of technological competition under increasing returns. Intuition suggests that if choices were made in a forward-looking way, rather than myopically on the basis of comparisons among the currently prevailing costs of different systems, the final outcome could be influenced strongly by expectations. A particular system could triumph over rivals merely because the purchasers of the software (and/or the hardware) expected that it would do so. This intuition seems to be supported by recent formal analyses by Michael Katz and Carl Shapiro (1983), and Ward Hanson (1984), of markets where purchasers of rival products benefit from externalities conditional upon the size of the compatible system or "network" with which they thereby become joined. Although the initial lead acquired by QWERTY through its association with the Remington was quantitatively very slender, when magnified by expectations it may well have been quite sufficient to guarantee that the industry eventually would lock in to a de facto QWERTY standard.

The occurrence of this "lock in" as early as the mid-1890's does appear to have owed something also to the high costs of software "conversion" and the resulting *quasi-irreversibility of investments* in specific touch-typing skills. Thus, as far as keyboard conversion costs were concerned, an important asymmetry had appeared between the software and the hardware components of the evolving system: the costs of typewriter software conversion were going up, whereas the costs of typewriter hardware conversion were coming down. While the novel, non-typebar technologies developed during the 1880's were freeing the keyboard from technical bondage to QWERTY, typewriter makers were by the same token freed from fixed-cost bondage to any particular keyboard arrangement. Non-QWERTY typewriter manufacturers seeking to expand market share could cheaply switch to achieve compatibility with the already existing stock of QWERTY-programmed typists, who could not. This, then, was a situation in which the precise details of timing in the developmental sequence had made it privately profitable in the short run to adapt machines to the habits of men (or to women, as was increasingly the case) rather than the other way around. And things have been that way ever since.

III. Message

In place of a moral, I want to leave you with a message of faith and qualified hope. The story of QWERTY is a rather intriguing one for economists. Despite the presence of the sort of externalities that standard static analysis tells us would interfere with the achievement of the socially optimal degree of system compatibility, competition 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. Outcomes of this kind are not so exotic. For such things to happen seems only too possible in the presence of strong technical interrelatedness, scale economies, and irreversibilities due to learning and habituation. They come as no surprise to readers prepared by Thorstein Veblen's classic passages in *Germany and the Industrial Revolution* (1915), on the problem of Britain's undersized railway wagons and "the penalties of taking the lead" (see pp. 126–27); they may be painfully familiar to students who have been obliged to assimilate the details of deservedly less-renowned scribblings (see my 1971, 1975 studies) about the obstacles which ridge-and-furrow placed in the path of British farm mechanization, and the influence of remote events in nineteenth-century U.S. factor price history upon the subsequently emerging bias towards Hicks' labor-saving improvements in the production technology of certain branches of manufacturing.

I believe there are many more QWERTY worlds lying out there in the past, on the very edges of the modern economic analyst's tidy universe; worlds we do not yet fully perceive or understand, but whose influence, like that of dark stars, extends nonetheless to shape the visible orbits of our contemporary economic affairs. Most of the time I feel sure that the absorbing delights and quiet terrors of exploring QWERTY worlds will suffice to draw adventurous economists into the systematic study of essentially historical dynamic processes, and so will seduce them into the ways of economic history, and a better grasp of their subject.

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