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# Understanding the Economics of QWERTY: the Necessity of History

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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 in 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 purposes 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 to those waiting to hear if and why the study of economic history is a necessity in the making of good economists.

By now you know that I want to dodge the question of the place of economic history courses in the proper training of economists. But before plunging ahead, I suppose I had better confess my reason for not seriously confronting the pedagogical issues raised by the statement that history is a necessary though not sufficient condition for the making of an economist: I suffer from what is undoubtedly a socially inappropriate reaction to the absurd state of affairs which seems to call for such reaffirmations. I get a mild case of the giggles. It puts me in mind of nothing so much as the title of a book written by James Thurber and E. B. White, *circa* 1929: *Is Sex Necessary? or Why You Feel the Way You do.*[1] Now I imagine there are others who have a different, more embarrassed reaction when this topic is brought up. If you are a straight economist and public mention of the subject of instruction in economic history does leave you feeling edgy, let me suggest that you can make these proceedings more comfortable by substituting 'Sex' for 'History.' Whatever else happens, this should help you to keep your bearings – which often is difficult to do once you get deep into a methodological discussion. The other thing you can try is to remember that the economic historians among you today are not alien creatures, but 'flesh of your flesh,' so to speak. Being children of the parent discipline of Economics, they are as much the subjects for condolences as for congratulations. Upon them the gods too often have visited the sins of the fathers. I'll talk about that problem another time, however.

Actually, if now we have agreed upon the notation: economists = 'parents,' economic historians = 'children,' and history = 'sex,' what Thurber and White's book has to say is quite suitable to the present occasion. I refer to the beginning of their chapter VI, entitled 'What Should Children Tell Parents?', which runs along these lines. 'Many *children* come to me with the question, "What am I to tell my *parents* about *sex*?" My answer is always this: "Tell them the truth. When one approaches the subject in a tactful way, teaching a *parent* about *sex* should be no more embarrassing than giving instruction in personal pronouns. And it is less discouraging." '

Why not let economists find out about history in their own good time, instead of going through the awkwardness of trying to tell them about it? Thurber and White offered a candid answer, along the following lines: 'One's *parents* are never too old to be told facts. Indeed to keep them in ignorance is quite cruel, for it allows them to nourish the doubts and horrors of their imagination. The majority of *parents* pick up their information about *sex* from smoking-car conversations, bridge-club teas, and after-dinner speakers. They receive it from their vicious adult companions who are only scarcely less ignorant than they are and who give them a dreadfully garbled version of what they should know.'

If economists are not to be left to pick up an historical approach to their subject 'from the gutter,' as it were, then responsible folk must sit them down soon or later and tell them about it. Finding a way to do this, of course, is the great problem which every thoroughly modern economic historian must overcome. To paraphrase the advice in Thurber and White's manual: 'When imparting *sex* knowledge to one's *parents*, it is of the utmost importance to do it in such a way as not to engender fear or anxiety. Choose your phrasing carefully, explaining everything clearly while avoiding the use of terms that tend to cause nervousness in *older* people.'

So now for a short, matter-of-fact story. I have selected it with especial care, adhering to Thurber and White's recommendation to omit any allusions to birds and flowers, or other confusing biological analogies which economists are likely to take too literally and find upsetting.[2]

## *The Story of* QWERTY

Why does the topmost row of letters on your personal computer keyboard spell out QWERTYUIOP, rather than something else? Nothing in the engineering of computer terminals requires the awkward keyboard layout known today as 'QWERTY.' The Maltron keyboard, developed by a British team, offers to save typists time and motion by dividing keys into more efficient groups: 91 per cent of the letters used most frequently in English are on the Maltron 'home row,' compared with 51 percent on the QWERTY keyboard. QWERTY forces your hands to 'hurdle,' that is to jump upwards or sideways so that fingers can strike keys, about 256 times more often than the Maltron arrangement whose tilted keyboard makes the letters easier to hit. But Maltron has arrived on the scene only recently, and we are all old enough to remember that QWERTY somehow had been passed down to us from the age of typewriters.

Clearly the computer manufacturers had not been persuaded by previous exhortations to discard QWERTY – even those which latter-day apostles of DSK (the Dvorak Simplified Keyboard) inserted in trade journals such as *Computers and Automation* during the early 1970s. 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. In the age of the manual typewriter the racing handicap imposed by QWERTY was especially heavy, except for those whose left hand and little fingers were uncommonly strong. Moreover, during the 1940's US 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 was a Professor of Education at the University of Washington in Seattle. He had lived his professional life as a disciple of Frank B. Gilbreth, the pioneer of time and motion studies and champion of the cause of designing 'machines for men not men for machines.' But he died, in 1975, a disappointed man. Had Dvorak construed Gilbreth's motto more literally and thought about the actual men and women who constituted the available supply of typists at the time, he might have spared himself the embittering frustration of the world's stubborn rejection of his contributions. As it was, his death 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 vexed by doubts that the switch would not often be flicked, and would remain more of a *curiosum* than a real selling point.

If as Apple advertising copy says, DSK 'lets you type 20–40% faster,' why did this superior design meet essentially the same resistance as the previous seven improvements on the QWERTY typewriter keyboard that were patented in the US and Britain during the years 1909–24? Was it the result of customary, non-rational behavior by countless individuals who had been socialized to carry on in an antiquated technological tradition? Or had there been a conspiracy among the members of the tyewriter oligopoly to suppress an invention which it was feared would, by increasing the productivity of each typist, ultimately curtail the demand for their machines? Dvorak himself once suggested that something like this lay at the root of the typewriter manufacturers' apparent disinterest in his patent. But 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?

Somehow 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 Tolstoi wrote in *War and Peace* (Bk. IX,ch. 1), '(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 . . . .'

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 printer by trade and mechanical tinkerer by inclination. Helped by his friends Carlos Glidden and Samuel W. Soule, who also spent much of their time hanging around C. F. Kleinsteuber's machine shop on the northern edge of Milwaukee, Wisconsin during the 1860s, 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 for 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 would stick at or near the printing point, every succeeding stroke would merely serve to hammer the same impression onto the paper. But the resulting string of repeated letters would be discovered only at the end of the paragraph, or whenever the typist bothered to raise the carriage to inspect what had been printed. Unsticking jammed typebars was a correspondingly awkward and time-consuming maneuvre, compared to which the jumps and slips of the weight-driven carriage escapement mechanism, or the tendency of the weight itself to come loose and crash onto the operator's foot, were merely secondary annoyances.

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.' It was during this painful interval that a four-row, upper case keyboard approaching the modern QWERTY standard emerged, from the inventor's trial-and-error rearrangement of the original model's alphabetical key ordering in an effort to reduce the frequency of typebar clashes. Vestiges of the primordial layout remained, as they do to this day in the 'home row' sequence: FGHJKL, with 'I' close by in the second row. In March, 1873 Densmore, with the help of a smooth-talking salesman who went by the name of George Washington Yost, 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, William Jenne and Jefferson Clough. 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 '.'.

QWERTY thus had evolved primarily as the chance solution to an engineering design problem in the construction of a typewriter which would work reliably at a rate significantly faster than a copyist could write. Marketing considerations also may have played some role in Jenne and Clough's final keyboard shuffles; it has been suggested that the main advantage of putting the R into QWERTY was that it thereby gathered into one row all the letters which a salesman would need, to impress customers by rapidly pecking out the brand name: TYPE WRITER

Nevertheless, the early commercial fortunes of the machine with which QWERTY's destiny had become linked remained extremely precarious. The economic downturn of the 1870s was not the best of times in which to be selling Americans a novel piece of office equipment costing $125 apiece. When the Depression lifted, early in the 1880s, Remington's sales of the Improved Model Two (introduced, complete with recently patented carriage shift key, in 1878) began to pick up pace; annual typewriter production reached the rate of 1200 units in 1881. But the market position which QWERTY had acquired during the course of its early career was far from deeply entrenched; the entire stock of QWERTY-embodying machines in the US could not have much exceeded 5000 when the decade opened.

Its future also was not 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 to mention those already established in Europe. A down-stroke design with an 'almost visible' printing point would be patented by Charles Spiro and introduced in New York as the 'Bar-Lock' typewriter in 1889, to be followed a year later by the first fully visible down-stroke machine, manufactured by the Daugherty Typewriter Co. of Pennsylvania. By 1893 Francis X. Wagner's superior design for a front-stroke visible machine with a four-row keyboard was patented, and in another three years it would be taken over by John Underwood's typewriter-supply firm to become the prototype for all the following upright front-stroke machines. Front-stroke action and visibility would greatly mitigate the problems of typebar jamming which were the original rationale for QWERTY's existence.

Meanwhile, back in 1878 when Remington had just brought out the Model Two and the whole enterprise was teetering on the edge of bankruptcy, the print-wheel offered a more radical but immediately available alternative to the typebar technology. It had been used in the Englishman John Pratt's typewriter of 1866, the fateful description of which, in the magazine *Scientific American*, had been shown to our hero Sholes during the following year by his friend Glidden. Furthermore, a patent had been filed for an electric print-wheel device in 1872 by a young mechanic at the Automatic Telegraph Co. in New York. This was none other than Thomas Edison, who, having helped improve one of the many Sholes–Glidden experimental models around 1870, then set out to prove that he could build a better instrument for printing telegraphs than the machine which Densmore and Sholes were urging upon his employers. This particular Edison invention went on to be used in teletype machines, leaving the instrument introduced in 1879 by a former Remington employee, Lucien Stephen Crandall, the honor of being the second typewriter to reach the US market. It was also the first commercial entrant that circumvented the problem of clashing typebars by dispensing with them entirely, in favor of an arrangement of 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 'golfball' design.

Very soon thereafter, in 1881, the first units of James Bartlett Hammond's alternative to the typebar system entered the American market using a swinging type-sector to insure perfect alignment and a rubber buffered hammer located behind the paper to achieve evenness of impression. While Hammond's first model was offered with a curved two-row keyboard, with the introduction of his Model Two in 1893 a square three-row layout also became available. Freed from the legacy of typebars, the arrangement of keys offered by the Hammond from the outset was more sensible than QWERTY: its 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 same, ideal layout later appeared on the small type-wheel portable with a three-row keyboard and double shift, first patented in 1889 and marketed as the Model Five by the Blickensderfer Manufacturing Company in 1893. (Notice that Dvorak also used these ten letters in his keyboard's home row, AOEUIDHTNS, except for the replacement of the R with U.)

The beginning of the typewriter boom in the 1880s had 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 microtechnological rationale for QWERTY's dominance was being removed by the progress of typewriter engineering, the US industry was rapidly moving toward the standard of an upright front-stroke machine with a four-row QWERTY keyboard that was referred to as 'The Universal.' The authorities disagree as to the exact dating, but it appears that sometime around 1896 George Blickensderfer started to offer 'The Universal' as an optional alternative to the Ideal keyboard on the various machines in the illustrious 'Blick' line. Hammond too seems to have fallen into step, offering the same option at least by 1905.

## *Basic QWERTY-nomics*

To understand what had happened in this fateful interval, 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. This system involved typewriter operators as well as typewriting machines, and therefore the relevant decision agents within it included others besides the makers and buyers of typewriter hardware: there were the typists who supplied a skilled labor service to employers, and the variety of organizations, both private and public, undertaking 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, this larger system of production was nobody's design. It was not conceived at the outset, in the dreams of Sholes, Glidden, Densmore or Philo Remington. Rather like the proverbial Topsy, and much else in the history of economics besides, it 'jes' growed.'

Instruction in typewriters began to be offered by private business colleges in New York City soon after the first Remington-built machines became available, but emphasis was placed upon mastering the mechanical operations rather than typing *per se*. In 1880 the firm of N. T. Underwood issued one of the earliest instructional handbooks containing 'inductive exercises, arranged with a typical guide to correct use of the fingers;' only some of the fingers, however. It was not until 1882 that the radical innovation of an eight-finger typing method was put forward by the proprietress of Longley's Shorthand and Typewriter Institute, in Cincinnati. Her pamphlet happened to be 'adapted to Remington's perfected typewriters.' That very same year, the New York firm of Wyckoff, Seamans & Benedict, having just bought the world-wide sales agency rights for the Remington Type Writer from the firm of E. Remington & Sons, began to promote their product by imitating another instructional innovation that lately had been introduced by the City's Central Branch of the YWCA. The 'Y' had organized an experimental class to teach eight young women to typewrite during 1881 and, despite critics' predictions that typewriting was destined to remain a masculine occupation, every one of the female graduates had found employment quickly. Remington schools for typewriting soon joined the private business and stenographic 'colleges' that were now springing up in all the leading cities.

But Mrs L. V. Longley's *Typewriter Lessons* were not sufficient to carry the day immediately for the proponents of eight-finger typing. She was denounced repeatedly in the pages of *Cosmopolitan Shorthander* and eventually was challenged to prove her case by another teacher of typewriting from her own city. The challenger, one Louis Taub, proclaimed the superiority of four-finger typing on the Caligraph. This was a rival machine which had been brought out in 1881 by Densmore's former partner, Yost. It came equipped with a six-row keyboard, accommodating upper- and lower-case keys to make up for its lack of the Remington's shift-action. In 1888, when the first public speed-typing competition was organized which put to the test these contending systems, the honor of Mrs Longley and the Remington was vindicated by a Federal Court stenographer from Salt Lake City who had taught himself to type on a Remington No. 1, way back in 1878. Frank E.

McGurrin, the man who entered the lists as their champion against Louis Taub, already had won fame in demonstrations before gasping audiences throughout the West, because, in addition to deploying the 'all-finger' technique, he had memorized the QWERTY keyboard. We shall never know whether he could have managed the same feat with the 72 keys of the Caligraph machine.

The advent of 'touch' typing, the name coined for McGurrin's method in a manual of typewriter instructions published in 1889, gave rise to three features of the evolving production system that were crucially important in causing QWERTY to become 'locked in' as the dominant keyboard arrangement. These 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 US Navy, not your typical employer, who undertook the experiment of retraining typists on the Dvorak keyboard.) The investment decisions of would-be touch typists, and the consequent supply of clerical and office workers with those skills, therefore remained largely beyond the individual control of the buyers in the market for typewriter hardware. 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. There, typists' decisions to learn the QWERTY keyboard would raise the value of QWERTY-equipped machines to their employer-owners. By increasing the likelihood that such machines would be installed in preference to others, such a decision raised the probability that another prospective typist subsequently would opt to be trained in a QWERTY-based method.

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 inter-system competition to lead toward *de facto* standardization through the predominance of a single keyboard design. For analytical purposes, the matter can be simplified by supposing 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. The candidates for typewriter instruction, on the other hand, may be supposed to have been 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. If we imagine the members of this heterogeneous 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 Arthur, Ermoliev and Kaniovski[3] allows us to say that when generalized forms of such processes (characterized by increasing returns) are extended indefinitely, the selection probabilities eventually approach a limit function (if one exists) and 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 beginnings of the process. It is there that essentially random, transient factors are most likely to exert great leverage, as has been neatly shown by Arthur's model[4] 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 the expectations that investors in system components – whether specific touch-typing skills or typewriters – came to hold regarding the decisions that would be made by the other agents. 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 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: Katz and Shapiro[5] and Hanson[6] have recently demonstrated the crucial role played by expectations in both static and dynamic duopoly games of this kind respectively. Thus, although the early lead acquired by QWERTY through its initial 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 1890s does appear to have owed something also to other causes. Conventional *economies of scale* were part of the story, as these soon were exploited by the private business colleges that taught young men and women to touch-type through the use of instruction manuals. Those organizations' impact upon the supply of QWERTY-habituated typists remained minor by comparison with the public high school systems that at a much later point, in the 1920s, began to include typewriting among their expanding curriculum of 'business' subjects. Nevertheless, the activities of business and commercial colleges offering stenography and typewriting during the late 1880s and early 1890s brought them into contact with both prospective employers and typewriter companies' sales agencies. Considerable leverage was thereby given to the numerically tiny cadre of pioneer touch-typing teachers who had become habituated to using the QWERTY keyboard.

The strategic significance of this latter point is brought out more fully by considering the third critical element among those I enumerated as having been added by the innovation of touch-typing. This was the high costs of 'software conversion', and the consequent *quasi-irreversibility of investment* in labor force training. The human capital formed in learning to touch-type is remarkably durable, for the skill resembles that of bicycle-riding or swimming in that once mastered it is long retained at some functional level and may be upgraded rapidly by practice. Moreover, once a specific touch-typing program has been 'installed in memory' it becomes quite costly (in retraining time and typing errors) to convert the afflicted typist to a different program. Thus, as far as keyboard conversion costs were concerned, an important asymmetry had appeared between the software and the hardware components of the evolving typewriting 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 1880s were freeing the keyboard from technical bondage to QWERTY, by the same token typewriter makers were freed from fixed-cost bondage to any particular keyboard arrangement. Manufacturers who adopted those engineering advances found it very inexpensive to provide the QWERTY option to any customers who might prefer it to the other keyboards they were being offered. A market inducement for producers to standardize voluntarily, at least in this one attribute, had arisen with the demonstrated superiority of QWERTY-based touch-typing over the four-finger hunt-and-peck method. Curiously, no public trial seems to have been held during the 1890s to determine whether or not a hunt-and-peck typist using the more efficient, Ideal keyboard also could be bested by the likes of Frank McGurrin (using QWERTY). But it is not clear whether the outcome would have mattered at all by that time.

It was enough that non-QWERTY typewriter manufacturers could switch cheaply to achieve compatibility with the QWERTY-programmed typists, who could not. For a producer newly entering the typewriter market the short-run attractions surely lay in the direction of expanding market share quickly. And this would mean catering to the needs of the extant 'installed base' of QWERTY-programmed typists, though it must still have been quite small even a decade after McGurrin's 1888 victory over Taub. My own estimates for 1900, based on a sampling of the manuscript schedules of the US Census in that year, indicate that there were some 8200–9200 gainfully occupied typists ('type-writers,' they were called) in the country, of whom at least 5500 had entered the pursuit during the preceding ten years when QWERTY-based touch-typing was coming into vogue. Since at this time American women typically left the workforce at marriage, and the mean age at marriage was declining among the white native born who dominated the ranks of female office workers, the potential personal typewriter market represented by the stock of QWERTY-trained typists must have struck contemporary observers as considerably larger and expanding steadily. This, then, was a situation in which the precise details of timing had made it privately profitable in the short run to adapt machines to men (or, as was the case increasingly, to women) rather than the other way around. And the business has continued that way ever since.

## *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 *de facto* standardization *on the wrong system* – and that is 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*[7], on the problem of Britain's under-sized railway wagons and 'the penalties of taking the lead;' they may be painfully familiar to students who have been obliged to assimilate the details of deservedly less renowned scribblings of mine[8] about the obstacles which ridge-and-furrow placed in the path of British farm mechanization, or the influence of remote events in nineteenth-century US factor price history upon the subsequently emerging bias towards Hicksian labor-saving improvements in the production technology set for 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 none the less 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 own subject matter.

But will it? Messrs Thurber and White[9] concluded their chapter with a gentle warning not to bet too heavily on the passive approach to educating a parent, along these lines: 'Sometimes it may be advisable to quote to your *parents* directly from standard works on the subject of *sex*. When this is felt to be too abrupt, less intrusive approaches may seem attractive. Some *children* have told me that instead of quoting from books they have left the books lying around, opened at pertinent pages. But even this has failed to work in most cases. A book that is lying around soon will seem dusty to the average *parent*. The "mothers" will usually pick it up, dust it, and close it.'

## *Notes*

1 James Thurber and E. B. White, *Is Sex Necessary? or Why You Feel the Way You Do*, Garden City, New York: Blue Ribbon Books, 1929.

2 What follows is an expanded version of the text that was published under the title 'Clio and the Economics of QWERTY' in *The American Economic*

*Review, Papers and Proceedings*, vol. 75, no. 2 (May, 1985), pp. 332–7. It does not reflect the voluminous correspondence I received subsequent to the Dallas, Texas Meetings of the A.E.A., on the subject of typewriters, their keyboards, other illustrations of path-dependent dynamic processes, and their mathematical representations. I am grateful for the support that the limited piece of research, reported on here, received under a grant to the Technological Innovation Program of the Center for Economic Policy Research, Stanford University. Douglas Puffert supplied able research assistance. The text and references record some but not the whole of my indebtedness to Brian Arthur's views on QWERTY and QWERTY-like subjects. I bear full responsibility, naturally, for errors of fact and interpretation, as well as for the peculiar opinions on the necessity of history (and sex) represented in these pages.

3 W. Brian Arthur, Yuri M. Ermoliev and Yuri M. Kanlovski, 'On Generalized Urn Schemes of the Polya Kind,' *Kibernetika*, vol. 19, no. 1, (1983), pp. 49–56, translated from the Russian in *Cybernetics*, vol. 19 (1983), pp. 61–71. W. Brian Arthur, Yuri M. Ermoliev and Yuri M. Kaniovski, 'Strong Laws for a Class of Path-Dependent Urn Processes,' in *Proceedings of the International Conference on Stochastic Optimization, Kiev 1984*, Berlin: Springer Verlag, 1985.

4 W. Brian Arthur, 'On Competing Technologies and Historical Small Events: The Dynamics of Choice Under Increasing Returns,' *Technological Innovation Program Workshop Paper*, Department of Economics, Stanford University, November 1983, 31 pp.

5 Michael L. Katz and Carl Shapiro, 'Network Externalities, Competition, and Compatibility,' *Woodrow Wilson School Discussion in Economics No. 54*, Princeton University, September, 1983, 34 pp.

6 Ward A. Hanson, 'Bandwagons and Orphans: Dynamic Pricing of Competing Technological Systems Subject to Decreasing Costs,' *Technological Innovation Program Workshop Paper*, Department of Economics, Stanford University, January 1984, 34 pp.

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