



Discussion

Comment on Neil Kay's paper—'Rerun the tape of history and QWERTY always wins'

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Every so often a paper comes along and applies theoretical reasoning to settle some particular question in history. Neil Kay's is such a paper, and it settles two seemingly trivial questions in technology history: whether it is a coincidence inherited from the past that the top line of our typewriter keyboards can spell out the word TYPEWRITER (Kay argues it is not); and whether it is speculation that the keyboard's layout was designed to prevent jamming (Kay again argues it is not). These questions are part of how the QWERTY keyboard came into being – again an historical question of seemingly limited importance. But QWERTY, as a standard – or better as an example of what the market has served us up in the long evolution of one particular technology – has become in economics a focal point, a rallying point for a larger issue: whether the market can lock us into an inferior standard. And this itself is part of a still larger issue: whether the free markets of capitalist economies can drive us into inferior outcomes.

Kay's paper makes beautiful use of probability theory: Two keys hit successively tend to jam if they happen to be alongside on the keyboard, so what are the chances of a keyboard jamming, given the frequency of successive letters – kh or nl or gd for example – in English as taken, say, from Mark Twain's *Huckleberry Finn*? And what are the chances for that matter of a given keyboard spelling out TYPEWRITER on the top row? Kay works out these probabilities and the results are instructive. But it is the larger market issues that I want to talk about in the light of Kay's paper.

Let me go back to some history of my own. The original paper I wrote on this subject Arthur (1983) barely mentioned typewriter keyboards; it was largely theoretical. I had become fascinated by the notion that technologies as well as firms or products competed, and it was clear that technologies improved as they were used and gained market share. Therefore, if by some cumulation of chance events one technology got ahead, it would likely get further ahead and could come to dominate; there would be multiple possible outcomes, with no guarantee that the best would prevail. Economics was aware of this problem – at least vaguely. Marshall, in a famous footnote to his 1890 text, had speculated about firms

with decreasing costs competing and foresaw that the market would go to "whatever firm first gets a good start." But *which* firm that might be was indeterminate, and this left the outcome, at least for static theory, indeterminate. I saw that the indeterminacy could be solved by viewing the market's buildup dynamically, as a random process, and watching it fall into one outcome in one realization, another in another one.

My purpose, then, was to show the process by which lock-in occurs and an outcome is selected. Paul David, my colleague at Stanford, writing two years later (David, 1985) had a different motivation, I believe. At the time, economic history was under siege in the graduate studies curriculum. Theory had taken over, and with it came for many economists a misguided impression that because equilibrium outcomes were unique (which was not correct theoretically), the economy we possess at any time was largely inevitable. How it was arrived at it was therefore irrelevant – just so much detail that caused perturbations along the way – and so history did not matter. David took up the typewriter case to argue that history *did* matter and the result was his QWERTY paper. It was an instant classic, and it caused a small sensation when presented to the economic historians at the January 1985 American Economic Association meetings. Their subject mattered after all.

David argued that QWERTY was by no means the best historical outcome, and for rhetorical purposes he needed a superior alternative that did not prevail. He chose the famous 1932 keyboard of August Dvorak, and that was where the trouble began. There ensued a debate, fueled largely by well-written papers by the pro-QWERTY economists, Liebowitz and Margolis (e.g. 1990). Was QWERTY really inferior to Dvorak, and could that be proved? Had it ever been proved? *Would* it ever be proved? The arguments went back and forth. Kay himself gets into the debate at the end of his paper: typewriters still tended to jam until the IBM golf ball appeared in 1961, and he shows, again using probability theory, that the Dvorak keyboard would jam more often than QWERTY did, so on this criterion, even if Dvorak had gone head-to-head with QWERTY at any time until 1961, it would have lost. Two points then

to Liebowitz and Margolis for QWERTY once more being shown superior – and two points earlier to Paul David for getting the details of the history right.

Where then does this leave us with the famous QWERTY debate? My own attitude, *pace* all the protagonists, is that this particular debate has always been the wrong one. The correct question is whether economic markets can lock in to inferior outcomes. And yet the QWERTY vs. Dvorak debate lives on, so let me say a few words about it on its own terms.

First, David's claim was that with QWERTY, "markets drove the industry prematurely into standardization on *the wrong system*" [David's italics]. The onus is not on Paul David to show that QWERTY was inferior to one possible keyboard, Dvorak. The onus is on his critics to show that QWERTY is superior to all other possible keyboards. I calculate that there are 2,658,271,574,788,448,768,043,625,811,014,615,890,319,638,527,999,999,999 of these, an admittedly large number (some 10^{54}). So even if someone finally and convincingly proves Dvorak inferior to QWERTY, this only goes part way toward proving QWERTY's superiority; the critics still have all the other cases before them.

Second, David's paper is not a mere investigation of typewriter history. It is an allegory, a parable, a tale told for economists to ponder and learn from, though one nonetheless grounded in historical evidence. Taken as a teaching parable, the persistent questioning of it always makes me imagine putative US Naval studies in which after 10,000 trials of tortoises and hares, not once did the tortoise win. That may be, but it misses Aesop's point – that dogged patience can sometimes prevail over flashy talent; or in David's case, that because standards must share compatibility, they tend to lock in, with no guarantee they do so to the "best" outcome.

Third, and once again, the debate very obviously is not about keyboards. It is about an ideology, in this case the libertarian one that markets steer us to the correct outcome. I have never been keen on economic theories driven by ideology, even if well argued; rarely does that lead to good science. Indeed, the whole debate is starting to look tired. Academic debates start as seemingly legitimate, then become heated, then dated, then largely forgotten. This ideological one I hope will mercifully reach the last stage soon.

What *can* we say about increasing returns and lock-in beyond the QWERTY debate? We have had thirty years or so to learn lessons. My own view is that lock-in and optimality are separate issues. Under increasing returns or decreasing costs, one product or technology or firm or standard or convention comes to dominate. To see this we need only look at the market shares of companies such as Facebook or Google, or the dominance of technologies such as the steam engine (that lingered long after the electric motor became available in the 1880s). Or the dominance of the English

language in world commerce, or of Latin in the middle ages, or of contractual conventions, or of social conventions such as shaking hands. Markets do lock in, and frequently. Optimality is a much trickier issue. Whether the market locks in to an "inferior" outcome depends on the criterion applied. Most often, a standard taken up at the outset is optimal for the people choosing. Later the criterion shifts and the now difficult-to-budge outcome looks non-optimal. Still later, the criterion possibly shifts again. Moreover, the criterion of "optimality" can be moved around by those who have axes to grind, so that virtually any outcome could be judged optimal if we choose the criterion strategically. Saying an outcome depends on historical accident is also tricky. What appears to be accidental at a coarse level may turn out to look inevitable at a more detailed level, then again to be largely accidental at a still more detailed level.

Yet the fact that we have to be careful about applying these terms does not negate increasing returns as a well-worked out body of theory. When I first embarked on this research, I was told that lock-in via increasing returns might be valid theoretically, but in practice it would be confined to a few small "anomalies" – typewriter keyboards, railway gages, maybe the occasional computer operating system. Now we are wiser. Increasing returns economics applies not just to standards, but to the whole high-technology sector (whose products share network externalities, learning-by-using advantages, and high R&D costs alongside low marginal production costs). It applies to the evolution of technology itself, to the theory and practice of economic development, to financial market theory, and indeed to allocation anywhere that there are positive feedbacks. It has become the basis of evolutionary game theory, the new growth theory, and the new international trade theory. We can say that under diminishing returns the economy tends toward unique, predictable, optimal outcomes; and under increasing returns or positive feedbacks it tends to multiple possible outcomes, not easily predictable, nor guaranteed optimal. Economics now has two complementary branches of theory that fit well together and in some situations are intermixed. QWERTY is very much part of the story of how this body of thinking has emerged, and it remains interesting, but we have traveled a long way beyond it.

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