Technological Inertia in Economic History

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Technological progress depends for its success on a conducive social environment. The resistance to innovation is identified as a central element governing the success of new inventions. Such resistance usually takes the form of non-market processes. It consists of vested interests, whose assets are jeopardized by new techniques, as well as by intellectuals who are opposed to new technology on principle. The role of resistance in the British and French economies during the Industrial Revolution is assessed.

Why are some societies technologically successful and others are not? Given the indisputable role of technological change in economic growth, one would have thought that economic historians should have spent a large proportion of their time trying to answer this question. Yet that turns out not to be the case. A. P. Usher, who has written and thought as much about the subject of technological progress as any one, did not attempt to answer this question directly. Ambitious historians with a global view, such as Eric Jones and Fernand Braudel, or leading historians of technology, such as D. S. L. Cardwell, Richard Hills, or Charles Singer rarely asked the question in this bald form, although their writing is required reading for those looking for the answer. Among the few venturesome scholars who have tried their hand at this question are David Landes and Lynn White whose pathbreaking hypotheses about medieval Europe are very rewarding.[1] Nathan Rosenberg and L. E. Birdzell's and my own recent efforts have added a number of hypotheses to the question of the sources of technological creativity.[2]

One factor that has not received sufficient attention in this literature is social resistance to technological progress. Given some successful inventions, how likely is it that they will be adopted and find their way into the production process? To what extent will a strong resistance to innovation discourage inventors and reduce the flow of new ideas? This

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Professor of Economics and History at Northwestern University, Evanston, Ill. 60208. I would like to thank Louis Cain, Charles Calomiris, Nancy Folbre, Jonathan Hughes, and Eric L. Jones for many stimulating conversations on these and related topics. Many of my graduate students have had to live through successive iterations of this paper and I thank them for the incisiveness of their criticisms and suggestions and for their patience. Jackie Olsen made excellent editorial suggestions.

[1] Landes, *The Unbound Prometheus* especially ch. 1. White, *Medieval Religion and Technology*. I should also mention Gille's comprehensive chapter on Technology and Society in his *Histoire des Techniques*. pp. 1241–77.

[2] Rosenberg and Birdzell, *How the West Grew Rich*. Mokyr, *The Lever of Riches*.

is obviously only part of the story: in economic history, there are no necessary or sufficient conditions for anything.

As in the history of international commerce, we have come to realize that writing economic history as if there were no political history is unacceptable. Understanding the political economy of technological change is necessary to understand the larger forces at work that determine which societies become technological leaders and how long such leadership lasts. At the same time, we need a coherent theory to analyze the interaction between political and technological elements. I believe that standard public choice and political economy can be enriched by supplementing them with ideas from evolutionary theory and systems analysis.

I

Adam Smith's greatest insight into the economy has been that it is a self-organizing system, one created not by human design but by uncoordinated human action. The idea of a self-organizing decentralized system, or "catallaxy" as Hayek has called it, is one of the most powerful and influential ideas of the modern age and perhaps the most important element in Smith's thought.[3] In the social sciences outside economics, self-organizing systems appear everywhere. Language, for instance is such a system, as are science, technology, the arts, manners, and so on. At the same time, self-organizing systems are increasingly becoming the basis of modern evolutionary biology.[4] These systems are all self-replicating ways of organizing information, and they change according to certain dynamic rules.[5]

For my present purpose, the most interesting property of these systems is that they resist change. Resistance to change is essential for any system if it is to function and not degenerate into chaos. Darwinian selection mechanisms pick and choose among existing species and mutations, a process that is the key to creativity in nature.[6] Creativity is evolution, and evolution proceeds through differential success. Creativity, however, has to be bounded and follow rules. Limiting selection through resistance to change is one of those rules. This is clearly not an optimizing rule; favorable mutations are frequently passed over because of resistance. Unlike natural selection, however, in cultural evolution

[3] Hayek, *Law, Legislation, and Liberty* Vol. 1, pp. 35–54; Vol. 2, p. 108. I am indebted to Lynne Kiesling for her advice on this matter.

[4] Much of this theory is the result of the work of a chemist, Ilya Prigogine. See Prigogine and Stengers, *Order out of Chaos*. In a recent paper, Stuart Kauffman noted that we have "begun to understand evolution as the marriage of selection and self-organization." See Stuart, "Antichaos and Adaptation," p. 78.

[5] Mokyr, "Punctuated Equilibria and Technological Progress," pp. 350–54. Mokyr, "Was There a British Industrial Evolution?" pp. 253–86.

[6] See the brilliant exposition by Dobzhansky, one of the greatest evolutionary biologists of our century, in "Chance and Creativity in Evolution."

there is a feedback effect; a high level of resistance will not only obstruct the adoption of new ideas but also discourage their emergence altogether, thus throttling the supply of the raw material of which change is made. Resistance does not imply complete inertness, but changes are typically local and controlled. Novelties and deviations from accepted standards are eliminated. An electrical appliance with a socket that does not fit the outlet will not sell, nor will a five-speed car with the gears arranged in a manner different from the customary pattern. In nature this elimination is ruthless; mutants usually do not survive, and even viable ones are typically either sterile or have lower fitness. In language, too, children are taught to speak and write *correctly*; that is, not to deviate from conventions and rules that have been laid down by past generations. Resistance to change can be observed in science, the arts, and religion.

Technological systems, like all cultural systems, must have some built-in stability.[7] Information is transmitted from generation to generation by the training of young workers, the writing of engineering textbooks, and continuous learning and mutual imitation. From the medieval peasant plowing his field, to the modern engineer using CAD to build a machine tool, conventions have evolved, and order is sustained as people cling to what they have been taught and equipment is made to conform to standards and customs. If the story ended there, however, history would be a dull tale indeed; marginal changes do not an Industrial Revolution make. Practically every self-organizing system has mechanisms that can overcome or fool the forces of inertia. How and when innovators achieve such success remains one of the most interesting questions in the economic history of technological change.

Looking at technology as a purely self-organizing system is an oversimplification. It is conceivable for a command economy to control the choice of technique and to initiate and approve any changes in production practices. Such systems have existed, in modified form, in Sung China and the Soviet Union. As Rosenberg and Birdzell have argued, free market economies are, on the whole, more likely to produce technological progress than centrally planned economies. Resistance to change tends to be more powerful in command economies. In a centralized bureaucracy there is a built-in tendency for conservatism. Sometimes the motives of technophobes are purely conservative, in the standard sense of the word.[8] For any bureaucracy, routine and standard operating procedures are the essence of its long run existence,

[7] For an introduction to the application of self-organizing systems to the theory of technological change, see Silverberg, "Modelling Economic Dynamics and Technical Change," Allen, "Evolution, Innovation and Economics."

[8] For an analysis of conservatism from an economist's point of view, see Kuran, "The Tenacious Past."

and deviancy is persecuted and uprooted.[9] As in any evolutionary system, diversity breeds creativity in technology; centralized bureaucracies, however, breed conformity. Yet in free market economies, too, technological creativity has proved rare and ephemeral. The history of technological progress is the history of an endangered and much resisted species.[10] Some resistance, as I indicated above, is inevitable. If every hare-brained technological idea were tried and implemented, the costs would be tremendous. Like mutations, most technological innovations are duds and deserve to be eliminated. Yet overcoming the built-in resistance is the key to technological progress; if *no* hare-brained idea were ever tried, we would still be living in the stone age. Unfortunately it is impossible to know in advance whether an invention is a true improvement or a dud until the experiments are carried out.

One problem for the historian, then, is to distinguish between resistance that protected the system from costly duds, and that which hindered progress and growth. Progress and growth, however, involved costs that usually fell disproportionately on some groups. Technological change invariably involved losers. Resistance to progress, when it came from a well-organized lobby of potential losers, served the narrow interests of a small and selfish group at the expense of the social good.[11] As Mancur Olson has pointed out, resistance to technological progress is only one of the ways in which what he calls distributional coalitions retard and possibly arrest the path of progress.

Why have historians paid so little attention to resistance to innovation?[12] Neoclassical economics in its most primitive form has no room for it. Resistance to technological change occurs because there is some "rigidity" in the economic system. In a perfectly competitive economy in which all capital—including human capital—is malleable and people can distinguish perfectly between successful inventions and duds, technological progress is a Pareto improvement. In such an economy technological unemployment cannot occur, and every worker displaced by a machine can find a job elsewhere without trouble. In the historical experience the irrelevancy of such models is apparent; the friction caused by technological shocks is an inseparable part of the story because technological change not only expanded the supply of re-

[9] Goldstone, "Geopolitics, Cultural Orthodoxy, and Innovation."

[10] Schumpeter, *The Theory of Economic Development*, pp. 86–87: "The reaction of the social environment against one who wishes to do something new . . . manifests itself first of all in the existence of legal or political impediments . . . surmounting opposition is always a special task which requires a special kind of conduct. In matters economic, this resistance manifests itself first of all in the groups threatened by the innovation, then in the difficulty of finding the necessary cooperation, and finally in winning over consumers."

[11] This argument was made in detail by Olson in *The Rise and Decline of Nations*, pp. 61–65.

[12] A recent exception is Randall's pioneering *Before the Luddites*. As Randall points out, mainstream economic history has treated the resistance to technological change, when it was noticed at all, as an "irritating minor impediment to the inevitable" (p. 3). See also Mokyr, "Progress and Inertia in Technological Change."

sources, it involved their transfer from the status quo to newcomers. The John Kays and Preston Tuckers of this world threatened existing plant, equipment, engineering skills, and the quiet life that is the best economic rent in a technologically stagnant world.

Labor, too, was a factor in resisting innovations. Since the early days of the Industrial Revolution, artisans and domestic workers feared that the machines would reduce the demand for labor and cause technological unemployment.[13] Economists and historians can show that, on the whole, better technology created as many jobs as it destroyed. Yet the new jobs were never the same as the old ones. Adjustment was not instantaneous, and during the period of search between jobs the worker was out of employment. Even Ricardo, in a bewildering appendix to his chapter on Machinery, concluded that rapid technological change could create temporary unemployment. Furthermore, technological change altered the non-pecuniary characteristics of labor. It created and destroyed labor hierarchies, changed the physical work environment, forced workers to migrate and disrupted families and communities. It made skills redundant, wiping out status and prestige, and it increased and decreased the advantages of domestic production in which workers were free from discipline and in control of their own work schedules. Insofar as such factors mattered and were not entirely reflected in compensating wage differentials, resistance to technological change by labor was likely. When labor unions expanded their power after the middle of the nineteenth century, they became a focus of resistance to technological change. All the same, blaming organized labor alone for the resistance is unwarranted. For the employers, too, life in a technologically creative world was different from that in a static economy. It is one thing to resist a once-and-for-all change in technology, quite another to resist living in a hectic and nerve-wracking world in which producers have to run to stay in place, constantly spending effort and resources searching for improvements.[14]

The central principle of the political economy of technological change is that resistance almost always takes place through non-market mechanisms, although non-competitive market behavior, such as denying innovators access to credit, has also been a widely-employed strategy. One method was through legal means: the technological status quo used government power through licensing, safety regulation, tariffs, and manipulation of education and research facilities to nip innovations in the bud.[15] An alternative was to use extralegal means: strikes and

[13] Berg, *The Machinery Question*; Calhoun, *The Question of Class Struggle*.

[14] This "Red Queen Effect" (after the Red Queen in Alice in Wonderland) has been noted by evolutionary biologists and plays an important role in generating adaptive changes in a world without exogenous environmental changes.

[15] In 1561, a Nuremberg coppersmith invented an improved slide rest lathe. Influenced by the

demonstrations, as well as illegal "Luddite" tactics such as arson, and other forms of personal violence have been highly effective means to combat innovation.[16]

Although non-market processes are not easy to model, we can try to catalog the elements that will determine the likelihood of success. First, the success of a potential innovation depended on the intensity of the opposition's motivation. The more specific and valuable the skill or piece of equipment being threatened with obsolescence, the more incentive its owner had to resist anything that reduced its value. At the same time, the greater the social gains from an innovation, the more incentive there was for innovators to fight for its success.[17]

Second, the degree to which the benefits and losses were concentrated among the winners and losers determined the extent to which political organization was possible on either side. Resistance consisted of collective action, and thus the usual free rider problem had to be overcome. Because consumers were almost always the final beneficiaries of technological change, the conservative forces seem to have had an advantage.[18] In some cases, however, the losers were more diffuse than the gainers. British handloom weavers were perhaps as seriously threatened by the powerloom as any interest group ever was, yet they did not succeed in slowing its adoption despite rioting in 1820s. At about the same time, agricultural laborers revolting against steam threshers succeeded in the "Captain Swing" riots to slow the diffusion of what they believed to be a threat to their livelihood. Groups that were geographically concentrated, working in old industries in which traditions and institutions protecting vested interest had time to gestate, and with closely-knit social and information networks, were more likely to resist innovation successfully. Experience with collective actions for other reasons made it easier to organize against machinery. Thus trade associations with a tradition of lobbying for protection were used against innovations, and trade unions that fought for higher wages and

guild of red-metal turners, the city council made him promise not to sell the lathe to anyone outside his own craft, then threatened to imprison anyone who sold the lathe.

[16] The Luddite movement in Britain was a complex phenomenon that was only partially inspired by aversion to new machinery. Stevenson, *Popular Disturbances in England, 1700–1790*. Thomis, *The Luddites*.

[17] An interesting example is the resistance to the printing press, which was waged by the scribes' guilds in the 1460s. As the social benefits were vast and the scribes did have presumably alternative occupations as clerks, resistance to printing did not last long. Yet the printers' guilds that protected the new status quo were far more powerful and managed to freeze printing technology until the Industrial Revolution. As late as 1772, the Basel master printers' guilds legally restrained Wilhelm Haas from constructing a heavier press made of metal parts.

[18] An extreme case of this kind is the incident in which the emperor Tiberius, who had interests in Roman glass manufactories, ordered the inventor of allegedly unbreakable glass to be strangled.

shorter hours were more effective in feather-bedding and other forms of resistance to growing efficiency.[19]

Finally, the attitude of the authorities is crucial precisely because resistance takes place outside the market. If power were held by persons with a stake in the technological status quo, policies would, of course, be conservative. Often matters were not so simple, however. Governments changed policy rapidly, as happened in France between 1780 and 1830, when attitudes toward technology oscillated from the conservative but weak policies of the last days of the ancien régime to the aggressive pro-technological attitudes of the Empire.[20] Moreover, different layers of government often pulled in different directions. For example, progressive modernization policies promulgated by central governments were undone by the maneuvering of special interests with local authorities in eighteenth-century Russia and Spain. When production was controlled by powerful guilds and trade associations, governments at times enforced the custom, while at others helped innovators circumvent the protective regulations. Strong governments took a firm stand against Luddites and even actively supported and encouraged innovation, as the experience of Czar Peter the Great and Napoleon I shows, but they could also become a stifling reactionary regime that suffocated all innovation, as was the case in Q'ing China.

As I have argued elsewhere, Britain's edge during the Industrial Revolution did not lie in the absence of resistance against technological change, but in its government's consistently and vigorously siding with the "party" for innovation.[21] Perhaps it is in this area that Douglass North's argument that Britain's advantage over other nations lay in its government and institutions carries the most force. In the preceding century this had not always been the case. By the late eighteenth century, however, the British government began to take an increasingly dim view of ancient laws such as the 1551 law that outlawed gig mills.[22] After feverish lobbying by both parties Parliament repealed it in 1809. The strength of the two parties varied from region to region, and in areas in which resistance was well-organized, such as the West counties, industry lost out and declined.[23]

Resistance to technological progress in France appears to have been more successful than in Britain, and perhaps this difference offers

[19] This point is also made by Randall for the West counties of England. See Randall, *Before the Luddites*, pp. 88–90 in correlating food riots in the West Counties with machine breaking.

[20] See McCloy, *French Inventions of the Eighteenth Century*. Alder, "Forging the New Order."

[21] Mokyr, *Lever of Riches*, pp. 255–61.

[22] The history of the gig mill is, indeed, a classic example of successful resistance to technical change. The machine emerged in the first half of the sixteenth century, and raised fierce resistance among workers in the finishing trade. In 1551, the machine was prohibited, and although traces of it appear in the seventeenth century under the term "mozing mill," it is clear that the law was enforced until the closing decades of the eighteenth century.

[23] Randall, "Work, Culture and Resistance."

another explanation why Britain's Industrial Revolution was "first." It is difficult, of course, to test exactly how large the difference was. In many occupations, powerful trade organizations known as *compagnonnages* controlled the trade and protected it from innovation. In the construction industry, for example, the powerful carpenters' guild managed for a long period to keep a monopoly over the details of material usage, and blocked the introduction of iron.[24] In papermaking, for much of the eighteenth century, the *compagnonnages*, by means of sabotage and arson, impeded the introduction of the *Hollander*, a machine that beat and cut the rags into pulp.[25] The woolen finishing trades in the North of France repeatedly resisted the introduction of British machines, though the exact effects of these riots are unclear.[26] Most portentous, perhaps, was the resistance of armorers to the pioneering attempts of Honoré Blanc to utilize interchangeable parts in the musket-making trade in the years before and during the French Revolution. In 1789, a crowd of furious artisans destroyed the workshop of a St. Etienne hardware manufacturer, Jacques Sauvade, who had shown an interest in mechanized mass production of flatware.[27] Possibly because of these and similar events, interchangeable parts have become known as the American System, although its French origins are by now well-known. Fifty years later a fate similar to that of Honoré Blanc befell Barthélemy Thimonnier, the inventor of a sewing machine using a chain-stitch mechanism. Again, the sewing machine would find the fertile soil it needed to grow and revolutionize the apparel-making industry across the Atlantic.

II

So far, the resistance to technological progress has been analyzed as analogous to protectionism. Resistance to technological change is, however, not limited to Olsonian coalitions defending their turf. A different source of resistance comes from purely intellectual sources who do not have necessarily a direct economic interest in the status quo, from people with a genuine concern for social or moral values. Schumpeter predicted that it would be intellectuals that would bring about a growing hostility to what he called the "capitalist order" (which in his thinking was inseparable from technological change).[28] Sorting out the motives of such intellectuals remains a complex task, although certain common trends can be discerned. Perhaps their influence was correlated with economic factors, but their intellectual motives were usually

[24] Guillerme, "Wood vs. Iron."
[25] See Gillispie, *Science and Polity in France*, p. 449.
[26] See McCloy, *French Inventions*, p. 184. F. Manuel, "The Luddite Movement in France."
[27] Alder, "Forging the New Order," pp. 36–39.
[28] Schumpeter, *Capitalism, Socialism and Democracy*, p. 154.

sincere enough and their influence was sufficiently long-lasting and powerful that we ignore them at our peril.

One can distinguish four different classes of motives in the writings of technophobic intellectuals.[29] One is what we would call a high risk aversion. By its very nature, technological change is risky in that it involves activities that have not been tried before and thus entail danger. There have been a number of cases in which the ex post costs of a new technology have in all likelihood exceeded the ex post benefits. Obvious examples include asbestos, chlorofluorocarbons, PCB's, lead-based paints and gasoline additives. Fear of such debacles propels many modern-day technophobes. The risk aversion involved may be such that projects with a very high expected value are abandoned because of a slightly higher variance of the outcomes. It is hard to argue that this is an irrational approach *strictu sensu* because the degree of risk aversion, however high, is a parameter of the utility function. It bears mentioning, however, that the distribution of risk is symmetric so that some historical inventions turned out to have had much larger benefits than ever expected, offsetting those that turned out to be costly duds. Even if technology misfires at times, such costs are inevitable and the problem can usually be corrected by applying diagnostic and corrective technologies.[30] Furthermore, safety considerations are sometimes cited sanctimoniously by existing interests trying to protect their turf.[31]

A second source of intellectual resistance to innovation is that technological change may decrease economic efficiency and welfare if it distorts the allocation of resources by creating negative externalities. There is an explicit assumption that new technology is relatively more inclined to make heavy use of scarce resources for which it does not pay. Barry Commoner's widely-cited statement that modern technology is an economic success because it is an ecological failure is a good case in point.[32] I interpret the statement to mean that new technologies create the need for the assignment of new property rights on resources that were previously considered free.[33] Assignment of these property rights runs into ever-rising marginal transactions cost, and in some cases

[29] I am excluding for this purpose the writings of such authors as E. F. Schumacher and Amory Lovins, as they seem to be not so much against technology as much as favoring particular forms of technology that satisfy different selection criteria.

[30] Modern technology created not only the CFC's that threaten the ozone layer but also provided Molina and Rowland with tools to detect the danger. Modern pharmaceutics can produce sunshield lotions that can keep out any level of UV radiation. See especially DeGregory, *A Theory of Technology*.

[31] A particularly interesting case, in which product quality and the alleged protection of the consumer were used to ward off innovation, is that of the American meatpacking industry in the 1880s, which pushed for passage of the meat inspection acts of 1890 and 1891 to try to avert the consequences of refrigerated railroad cars. See Libecap, "The First Federal Consumer."

[32] Commoner, *The Closing Circle*, p. 149.

[33] This seems to be the basis of much of the writing of Mishan; see especially Mishan, *Technology and Growth*.

constituted part of the value system that is the soil in which technological seeds must germinate.

We do have, after all, a puzzle in Victorian Britain, that has never been fully resolved. We need some explanation for the loss of technological leadership, which within two generations took Britain from workshop of the world to follower.[43] Many economic historians probably give little credence to Martin Wiener's thesis that Victorian Britain underwent a "counterrevolution of values" in which a new elite threw earlier enthusiasm for technology into disrepute.[44] Wiener's exaggerations notwithstanding, the attitudes to which he is pointing may have infected more people than was healthy for the economy.

What I am suggesting is that the resistance to technological change played an important role in the demise of Britain's leadership. Resistance after 1850 rarely took the form of extralegal action. It found its most effective routes through an anti-technological ideology which permeated the education system, and through labor relations, in which unions developed mechanisms to short-circuit new technologies. Examples are easy to find in the period after 1850.[45] Labor's growing resistance "reinforced the increasingly apathetic attitude of employers toward technological change," write Coleman and MacLeod.[46] It is important to stress that such mechanisms of resistance were not fool-proof and in many cases failed to stop new technologies, whether of domestic or foreign origin. By remaining loyal to free trade, Britain seriously curtailed the power of technologically reactionary groups to thwart innovation.[47] An open economy was a technological asset; Cardwell argues that without immigrants such as Ferranti, Marconi, Siemens, and others "there might have been virtually no innovation at all in Britain."[48] It is also quite true that resistance to new technology was strong in other countries, even those who are often regarded as overtaking Britain in technological leadership.[49] All the same, as resistance increased, no leadership from the British government was forthcoming to encourage and protect technological creativity. The laissez-faire policies that had served so well a century earlier were

[43] Cardwell, *Turning Points in Western Technology*, pp. 188–93.

[44] Wiener, *English Culture*.

[45] Joseph Whitworth in his famous report on the American System of Manufacturing in 1854, emphasized that British workers were far more hostile to new technology than their American counterparts, because they were more skilled, better organized, and less mobile. See Rosenberg, *The American System of Manufactures*. In industries as different as shoemaking, shipbuilding, cotton spinning, and printing, resistance was stiff.

[46] Coleman and MacLeod, "Attitudes to New Techniques."

[47] See Church, "The Effect of the American Export."

[48] Cardwell, *Turning Points*, p. 193.

[49] A curious example is the sharp resistance to the automobile in the land of its cradle, Germany. Blacksmiths, horsebreeders, and railroad investors formed a coalition which was intended to slow down its diffusion, and by 1914, Germany's production and ownership of automobiles was far lower than France's or Britain's.

slowly becoming an instrument for the defense of the technological status quo.

It would be an exaggeration to propose resistance in its different forms as the sole or even the most important cause of decelerating technological progress in Britain. Yet it would be equally unwarranted to dismiss it just because its effects do not lend themselves readily to measurement and testing.

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