array of huts, set within one or more rectangles of parallel horizontal strands of wire rising taller than a man's height, in full view of armed guards sitting above on unapproachable watchtowers.

Like another simple concept, the seaborne cargo container, this model had enormous leverage. It supported, indeed made possible, an entirely new level of repressive achievement. Railways carried millions of people across continents to the enclosures that awaited them, in replication of the means, methods, and scale of the transport of livestock for slaughter in the American west. A system first deployed to demarcate property rights in a possessive-individualist democracy worked just as well for repressive dictators in central and eastern Europe. The Soviet Union reliably herded and held millions of people in the service of its murky and murderous objectives. The modern civilization of Germany was captured by a cluster of zealots, who used railways, telegraph, and wire even more efficiently for their project of industrialized murder. Barbed wire continues to work silently at the interfaces of conflict all over the globe. A fast-paced and absorbing journey takes us from the Great Plains, one of the continental landscapes of modern economic growth, into darker and deadlier territory, culminating in Auschwitz, where the reader is finally left shaken and disturbed at the transformative potential of technology. It is a short book, whose grip never fails. It should be read widely; economic historians in particular will find it a timely reminder of how growth, development, and innovation have the power to disrupt human welfare, as well as to enhance it.

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Vaclav Smil, *Creating the twentieth century: technical innovations of 1867–1914 and their lasting impact* (Oxford: Oxford University Press, 2005. Pp. ix + 350. 115 figs. ISBN 0195168747 Hbk. £19.99/$35)

Vaclav Smil, *Transforming the twentieth century: technical innovations and their consequences* (Oxford: Oxford University Press, 2006. Pp. x + 358. 191 figs. ISBN 0195168755 Hbk. £26.99/$45)

These books provide comprehensive coverage of the technologies that have altered our world since the invention of the dynamo in 1867. They are a 'must read' for those interested in the details of technological change and they should be on the shelves of all students of economic growth, a valuable resource for browsing and reference.

They can be read as technological history. *Creating the twentieth century* (hereafter *Creating*) deals with the introduction of commercially-generated electricity, internal combustion engines, new materials, new chemical syntheses, and new methods of information and communication. *Transforming the twentieth century* (hereafter *Transforming*) deals with 'the fossil fuel society', materials new and old, rationalized production through mechanization, automation, and robotization, and new methods of transportation, communication, and information: automobiles, high-speed trains, commercial aviation, containers, and computers. The coverage is comprehensive, dealing with the precursors, inventors and their inventions, innovators, and subsequent applications and improvements. Case studies illustrate that there are few simple generalizations concerning technological change. For example, although

inventors are sometimes successful innovators, often the profits are reaped by independent entrepreneurs.

If there is one aspect of this excellent treatment that is weaker than the rest, it is the inducements leading to the innovations. For example, the innovations of the Japanese car industry are discussed without mentioning the key postwar policies that created a protected market too small for production at the Minimum Efficient Scale (MES) associated with US techniques. In response, Japanese firms developed new techniques that reduced their MES. They invented just-in-time inventories (discussed by Smil), and redesigned machines in important ways (not mentioned by Smil), such as developing dies changeable in minutes rather than the hours required by US firms. The costs associated with these lower MESs turned out to be below those associated with the MESs of US techniques, allowing the Japanese to challenge western manufacturers. In addition, Paul David's explanation of the origins of the QWERTY arrangement of typewriter keys is repeated without reference to his classic 1985 article and without noting the recent challenges to David's explanation or the resulting debate.

Furthermore, Smil states that the complex history of machine tools 'is surely among the most neglected topics in the study of modern technical advances' (p. 173), while making no mention of Nate Rosenberg's seminal 1963 article on machine tools. The impact of CADs on aircraft design is also studied in detail without mentioning its important result in greatly reducing the wasteful margins of error, studied by Rosenberg, that had to be incorporated into aircraft designed on the drawing board. Moreover, and surprisingly, lasers, one of the most multipurpose of modern technologies, are only mentioned once (p. 11). However, these are but minor complaints about this study of the vast majority of the period's important inventions and innovations.

These books also make a strong but controversial case for the technological uniqueness of the period 1867–1914, arguing that this was a time 'when the greatest technical discontinuity in history took place' (p. 4; all further references are to *Creating*), such that 'The fundamental means to realize nearly all of the twentieth century accomplishments were . . . in place even before the century began' (p. 5) with 'Neither the pre-1860 advances nor the recent diffusion and enthusiastic embrace of computers and the Internet . . . comparable with the epoque-making sweep and with the lasting impacts of that unique span of innovations that dominated the two pre-[First World] War generations' (p. 25). Earlier innovations 'had no scientific foundation' (p. 13), while the pace of later innovations has not accelerated and, in agreement with Robert Gordon (in the *Journal of Economic Perspectives*, 2000), the New Economy of the late twentieth century 'has not measured up to the truly great inventions of the past' (p. 5).

Smil sees five major characteristics of this period: first, 'the impact of the . . . advances was almost instantaneous' (p. 8); second, there was an 'extraordinary concatenation of a large number of scientific and technical advances' (p. 9); third, 'the [rapid] rate with which all kinds of innovations were promptly improved after their introduction' (p. 11); fourth, 'the imagination and boldness of new proposals' (p. 11); and fifth, 'the epoch making nature of these technical advances' (p. 12).

Undoubtedly, the period 1867–1914 contained a massive number of technological inventions and innovations. In particular, electricity and the internal combustion engine laid the foundations for much that followed. Indeed, electricity is one of the most pervasive 'general purpose technologies' of all time, a technology whose

complementarities are shown whenever a city suffers a power failure. However, the developments before this period were not as ad hoc as he claims. In my jointly authored (with Kenneth Carlaw and Clifford Bekar) study, *Economic transformations: general purpose technologies and long term economic growth* (2005) (hereafter *LCB*), we detail: first, the continued mutual feedback between early modern discoveries in science and the development of the steam engine; second, the mechanization of the textile industry over two centuries, following a programme laid out by Leonardo di Vinci in a path-dependent process that was anything but unsystematic, and which was greatly aided during the eighteenth century by the permeation of British society with a knowledge of Newtonian mechanics; and third, how knowledge of magnetism and electricity developed slowly along a trajectory begun by Gilbert's *De Magneta* in 1600 and was replete with understanding of commercial possibilities, which became real when the voltaic cell was invented in 1800, and appreciated fully when the invention of the telegraph in 1836 began the communication revolution. No doubt there was an acceleration of technological advance after 1867, and no doubt there was a much closer relation between science and technology as scientific knowledge expanded into non-mechanical areas and research laboratories were developed. However, we see this as thickening an existing interrelationship between science and technology rather than as a major discontinuity.

It is arguable that the pure scientific discoveries after 1914 were in some sense less fundamental than, and heavily dependent on, what went before, although it is hard to argue that the electronic computer was not a development of the post-1914 period—albeit with roots in earlier developments. However, I dispute the position argued by Smil (and Robert Gordon) that the *structural changes* caused by the later-twentieth-century ICT revolution paled in contrast with those caused by the innovations of the earlier period. We have given our reasons (*LCB*, pp. 114–19) so I only note here that our incomplete list of transformation caused by the ICT revolution covers several pages, including those in the structure of production and management, new methods of surgery, work moving from firms to homes, changes in the distribution of income, pervasive use of chips in consumer's and producer's goods, control of most transportation vehicles, computerized translations, and a fundamental alteration in international policy negotiations due to the surveillance from NGOs and their ability to organize protests quickly.

The disagreement arises partly from a confusion between the pure technology of the innovations which *may be* less fundamental now than previously, and induced changes in the socio-economic structure of the economy (what *LCB* calls the 'facilitating structure'), which are hard to see as less important today than a century ago. Although we might argue about magnitudes, qualitatively everything Smil says about the five characteristics of his period can be said about the later ICT revolution.

Smil's is a valuable statement of arguments for the technological uniqueness of the period 1867–1914. Many would agree with him in his comparison with the earlier period, and some with respect to the later period, while *LCB* presents opposing views. These debates are important in determining how we see the past as leading to the present. For example, the belief that we were not experiencing a major ICT-driven economic and social transformation in the last three decades of the twentieth century delayed many necessary governmental and private-sector reactions. Thus does debate need to be carried on at greater length elsewhere.

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