1. Introduction

Technological change is central to the study of economic growth in history. Strong and sustained technological progress is the key characteristic of modern economic growth that distinguishes the post-Industrial-Revolution world from earlier times and is the fundamental force that has raised living standards over the past 250 years. As Paul Romer said: ‘Our knowledge of economic history, of what production looked like 100 years ago, and of current events convinces us beyond any doubt that discovery, invention, and innovation are of overwhelming importance in economic growth’ (1993: 562).

Cliometrics is the use of economic analysis and econometrics by economic historians and practitioners. This implies a desire, where possible, to quantify, typically using techniques that would be learnt in graduate economics courses. In the context of technological change and long-run growth performance, growth economics is the most important intellectual resource. Growth economics has, of course, developed quite considerably since the early days of the new economic history in the 1960s, but it is probably fair to say that there has always been a tension between the economic historian’s wish list based on the richness of historical experience and what is actually on the menu. This represents a potentially useful challenge for economics but may also distort historical research.

Ideally, the relationship between economics and economic history would be a two-way street rather than a one-way street. A quarter century ago, however, Robert Solow saw a danger that the trajectory of quantitative economic history was such that ‘economic theory learns nothing from
economic history, and that economic history is as much corrupted as
enriched by economic theory' (1985: 328). Ironically, one of the best
eamples of this may be the inappropriate use by economic historians of
Solow’s own neoclassical growth model and growth accounting technique,
which seemed to be the only game in town during the early days of
cliometrics.

So, how much has the cliometric approach to the economic history of
technological change contributed? An answer to this question can be
developed by posing two further questions that this paper will address:

- What has been learnt from the use of economics to study technological
  change in an historical context?
- What are the important lessons for economics from cliometricians’
  investigations into technological change?

Before turning to these questions it may be useful briefly to consider what is
distinctive about the study of technological change by economic historians
as opposed to economists. The most obvious points to make are that
economic historians tend to have a much longer-run perspective and their
research agenda responds to a different historiography in which some of
the questions are posed by historians who do not necessarily share the
priors of economists. This has naturally led to a longstanding emphasis on
the role of institutions (North 1990), on endogenous innovation (Mokyr
1990) and on divergence rather than convergence in income levels across
the world (Maddison 1995). Moreover, at least since Gerschenkron (1962),
there has been a strong tradition of analysis that assumes not only that ‘one-
size-does-not fit-all’ but that there are systematic differences in the
appropriateness of institutions and policies at different stages of
economic development. These topics were not embraced by traditional
neoclassical growth economics but are, of course, quite central to the new
growth economics of the past 20 years. To some extent, this can be seen as
(implicitly) addressing issues that matter a lot to economic historians.
Finally, it should be noted that economic historians tend to believe that
‘history matters’ in the sense that the past constrains and shapes the
present and that ‘path dependence’ is an important aspect of the evolution
of economic policy and performance (David 1994).

2. Using economics to analyse technological change in history

In order to address the questions posed in the Introduction, this section
reviews some well-known episodes in the cliometric literature on
technological change. The coverage is, of course, selective rather than comprehensive but includes some famous controversies and in each case the topic has important implications for the field as a whole and for the issues with which this paper is concerned.

2.1. Solow’s residual

Solow (1957) was a landmark paper that introduced growth accounting to a wide audience and made explicit the economics of the sources of growth conceptualized in terms of moves along and shifts of the aggregate neoclassical production function. The concluding summary offered the startling claim that seven-eighths of the increase in American labour productivity between 1909 and 1948 was attributable to technical change. This method of analysis was adopted by economic historians, although typically with some modifications especially to take account of human capital, and research in this tradition has now produced macro-level historical growth accounting estimates for many countries and is still very active, as is reflected in the survey in Crafts (2009a). Given the centrality of explaining why growth rates differ for economic history, the apparent possibility of quantifying the contribution of technological change and comparing it across countries and over time has been very attractive to cliometricians.

Solow’s finding turned out to be an outlier and economic historians have come to recognize that total factor productivity (TFP) growth comparisons are quite difficult to interpret and not necessarily a good guide to comparative rates of technical change, a lesson that may be useful for economists more generally. Indeed, it is perfectly possible for measured TFP growth either to overestimate or underestimate technological progress.

Typically, for other countries and for the United States in other time periods, use of this technique finds (sometimes considerably) smaller shares for ‘crude TFP’ as a source of labour productivity growth. Where TFP growth has been very rapid and accounted for a large share of labour productivity growth, as in the European Golden Age of Growth after World War II, there are good reasons to suppose that a substantial part of the TFP growth represents improvements in scale economies and in allocative and productive efficiency rather than technical change (Maddison 1987, Jerzmanowski 2007). On the other hand, economic historians – including exponents of growth accounting – have always thought that embodiment of technological advance in new types of capital goods has been important, as also does endogenous-growth economics, in which case the contribution of...
technological change will exceed the TFP growth estimated using the standard methodology (Barro 1999).  

As this implies, it may not be appropriate to impose the standard growth-accounting assumptions of a Cobb–Douglas production function with neutral disembodied technical change. Abramovitz and David (2001) argue that the appropriate formulation of an aggregate production function for the United States in the nineteenth century (but not the twentieth century) would allow for capital-using bias in technological change and an elasticity of substitution of factors of production well below one. Accordingly, they suggest that TFP growth estimated using the standard assumptions is a considerable underestimate of the rate of technological change.

There is a deeper concern with the use of growth accounting to identify the sources of growth that was very clearly articulated by Abramovitz (1993) himself in his presidential address to the Economic History Association. The issue is interdependence: both between the opportunities presented by the nature of technological change for capital accumulation and between the trajectory of physical and human capital formation and technological change. While the latter is now stressed by some endogenous-growth models, it is actually the former that is highlighted by a comparison of the American growth process in the nineteenth and twentieth centuries.

Three key points emerge from this research. First, using conventional growth accounting to estimate TFP growth is not always a good guide to underlying technological change, as experienced practitioners have always known. Second, and perhaps more important for economic historians, the size and direction of the bias if TFP growth is taken as a proxy for technological change has varied considerably and this can make historical comparisons quite difficult even for those who are sympathetic to the use of this methodology. Third, while growth accounting invites its users to treat the growth of capital and technological change as independent and additive, this assumption is potentially quite misleading and may detract from a deeper understanding of the sources of growth.

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1 For example, as captured by the following comment from Charles Feinstein: ‘many forms of technological advance … can only take place when “embodied” in new capital goods. The spinning jennies, steam engines, and blast furnaces were the “embodiment” of the industrial revolution’ (1981: 142).

2 Endogenous-growth models of this type include Lucas (1988) and Romer (1987). Of course, in the neoclassical growth model, an increase in exogenous TFP growth raises the growth rate of the capital stock; some implications of this point for growth accounting are explored by Hulten (1979). However, Abramovitz has in mind a richer story about nineteenth-century American growth in which, inter alia, the great expansion of the domestic market resulting from technological change in transport leads to larger-scale and more capital-intensive methods of production.
2.2. The Industrial Revolution

The Industrial Revolution can be seen as the fundamental discontinuity in economic history representing the point at which modern economic growth began. As such, seeking to quantify the dimensions of economic growth is important but explaining why it happened when and where it did is the Holy Grail. It would be fair to say that cliometrics has been some progress on the former but the latter remains elusive. This reflects what economics has had to offer.

Estimates of economic growth in Britain during the Industrial Revolution have been revised considerably as better index numbers of output have been constructed, careful estimates of the capital stock have been made and growth accounting techniques have been deployed (Feinstein 1988, Crafts and Harley 1992). The upshot is that this period seems to be one where technical change, based on a number of well-known inventions, especially in textiles, the iron industry and in transport, did account for a high share of labour productivity growth. TFP growth accelerated significantly but not spectacularly from 0.1–0.2% per year to a sustained rate of about 0.8% per year between the 1760s and the 1830s, but the contribution of steam (the general purpose technology of the time) to labour productivity growth was negligible prior to 1830 and only rose to about 0.4 percentage points per year in the third quarter of the nineteenth century, nearly 100 years after James Watt’s patent (Crafts 2004).

It was remarkable that population growth of around 1.5% per year was absorbed without a serious decline in real wages, three times what had been possible in pre-industrial times, but growth performance was obviously quite modest by later standards with Gross Domestic Product (GDP) growth never above 2.5% per year in nineteenth-century Britain. Those familiar with modern growth economics, and especially ideas related to endogenous innovation, would find it quite easy to explain why growth was quite modest even in the most-advanced economy of the day, based on the limitations of the knowledge base, shortcomings of the capital market and intellectual property rights, small market size, and misallocation of talent (Crafts 1995). The low initial impact of steam can be understood in these terms since the science to advance the technology rapidly was not available and it took a long time to realize its potential in most sectors.

Explaining the timing and location of the Industrial Revolution is much harder. Here, for economists, there is a new game in town; namely, unified growth theory (Galor 2005), which proposes models where the economy moves from a Malthusian equilibrium through an endogenous industrial revolution and a demographic transition to modern economic growth with high human capital and rapid technological progress. In Galor and Weil
Nicholas Crafts

(2000), the trigger for the industrial revolution is an increase in population size that, of itself, raises the rate of technological progress; while in Galor and Moav (2002), a process of natural selection raises the share of families with a high valuation for children with more human capital.

While the technical sophistication of these papers clearly appeals to economists, this style of research is not likely to be persuasive to economic historians until the research agenda is modified explicitly to develop testable predictions; in particular, by confronting the issue of why technological progress accelerated rather than treating this as a scale effect with no specific mechanism.3 Explaining why Britain became unusually technologically progressive in the late eighteenth century has been the central agenda of economic history from Ashton (1948) through Landes (1969) to Allen (2009) and Mokyr (2009). There are still many competing hypotheses to explain this including the emphasis placed by Allen on the configuration of relative factor prices and the weight given by Mokyr to the role of the Enlightenment in British society. It is, however, generally agreed by historians that the technology of the Industrial Revolution resulted from successful systematic experimental effort, and it is the relatively high volume of this that needs to be explained; unified growth theory is not the place to search for plausible answers.

2.3. Social savings of railroads

Robert Fogel (1964) provided one of the most famous contributions to cliometrics with his investigation of the contribution made by the railroads, a new transport technology, to nineteenth-century American economic growth. His conclusion that national income in the United States in 1890 would only have been 4.7% higher than in the absence of the freight services of railroads and that the railroads were not indispensable to economic growth triggered off a massive controversy around the findings themselves and, more generally, the role of counterfactuals in economic history.4 The social-savings methodology has continued to be used in transport history, and recent contributions include Leunig (2006).

3 One exception to this statement is Gregory Clark, whose book A Farewell to Alms (2007) stresses the role of an increased share of middle-class genes and values. This contribution has not so far proved persuasive to the economic history profession; see, for example, the review essay by Allen (2008), which finds Clark’s argument to be without empirical foundation.

4 A subsequent paper by Boyd and Walton (1972) found that adding social savings for passenger travel on American railroads in 1890 would add a further 2.6% of GDP to the railroads contribution to national income. A good survey of the controversy written from a sympathetic but critical economic historian’s
The notion of social savings is the sum of consumer and producer surplus (if any) accruing from the new cheaper (at constant quality) technology. Under perfect competition, this would be the area under the demand curve and would be equivalent to the user benefits in a cost–benefit analysis. The translation to measuring the contribution to national income is then made by assuming that these transport benefits are equal to the total economic benefits. The natural interpretation is that this is the increase in TFP arising from the resource savings of the new technology. As such, it is equivalent to a subset of the contribution that would be estimated by growth accounting, as in Crafts (2004). However, unlike growth accounting, the capital-deepening contribution to labour productivity growth through investment in the new variety of capital goods is not added in. Fogel’s logic was that railroad capital earned normal returns and in the absence of railroads alternative normal-returns investments would have been made so only the TFP contribution is unique.

The social saving concept was devised to answer the question ‘how much faster was economic growth than it would have been in the absence of railroads?’, whereas growth accounting simply addresses the (easier) *ex-post* accounting question ‘how much did the railroads contribute to growth?’ So, does the social saving measure provide a good answer to Fogel’s question? It certainly was salutary to be reminded that a new technology may only need to be slightly cheaper to replace its predecessor and its resource saving may be quite modest. The difficulty lies in equating transport benefits to economic benefits. This will be valid only if there are constant returns to scale and perfect competition in the transport-using sector (Jara-Diaz 1986) and is not the case if there are externalities or external economies of scale, for example in the form of agglomeration benefits arising from changes in industrial location and the size of cities.

At the level of a massive change in transport networks, these effects might be quite substantial and long-lived. This was the essence of the critique in David (1969), and similar unease was expressed in non-technical ways by other economic historians who stressed the importance of linkage effects and market integration (O’Brien 1977), but Fogel (1979) was unwilling to accept that these issues matter. Modern economics, now formalized in terms of the new economic geography, encourages us to take these effects seriously and offers some scope for quantifying them such that they have

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5 Growth accounting is the approach normally adopted by economists today; see, for example, the literature on information and communication technology (ICT) (Oliner et al. 2007), which does include the capital-deepening contribution of ICT capital.
started to be included in government cost–benefit analysis (Crafts 2009b). The Chicago tradition to which Fogel belonged did not embrace these ideas and, in any case, cliometrics did not have a methodology to capture them.\(^6\) The problem then is not counterfactual history \textit{per se}, but the difficulties of relying on simple models to provide law-like statements that supply the counterfactual but are not persuasive to historians who feel their (legitimate) concerns are ignored.

2.4. Labour scarcity

One of the most famous cliometric debates was triggered by the publication by Habakkuk (1962), which argued that labour scarcity associated with land abundance promoted rapid, labour-saving technological change in the United States in the nineteenth century. More precisely, as Paul David (1975) underlined, three claims can be distinguished; namely, that labour scarcity led to the use of capital-intensive techniques (more machines), accelerated the rate of technological change (better machines), and encouraged a labour-saving bias in technological change. Surprisingly, perhaps, none of these turned out to be easy to justify.

The more machines aspect of the Habakkuk hypothesis needed careful handling both in terms of establishing the evidence on relative factor prices and consideration of production functions in different sectors of the economy and different sub-sectors of manufacturing, although it is clear that, informed by cost considerations, by the later nineteenth century technical choices were often very different from those in Europe where American technology was ‘inappropriate’. The best resolution of the issues was provided by James and Skinner (1985), who found that both labour and capital were expensive but natural resources were cheap in the United States compared with Britain. Land abundance \textit{per se} was not the real reason for capital-intensive production in US manufacturing, which in any case initially prevailed only in some industries; namely, those that used skilled labour where the United States was able to exploit complementarity between capital and natural resources to use less labour-intensive methods.

The suggestion that labour-saving inventions result from dear labour dates back at least to Hicks (1932: 124–5) but this hypothesis invites the objection that in equilibrium all inputs are equally ‘dear’ and that the

\(6\) Fogel (1979) points out that his crude estimate of social saving was deliberately upwardly biased by virtue of assuming a zero price-elasticity of demand for transport. This does not, however, guarantee an upper bound and it is striking that Fogel’s estimates are based entirely on agricultural freight which is assumed typical, whereas the big conceptual and measurement issues relate to transport of manufactured goods.
search for new knowledge should aim to reduce total costs not labour costs in particular (Salter 1960: 43–4). Nevertheless, it was widely believed that factor-saving bias was characteristic of the American economy; and this was subsequently demonstrated econometrically by Cain and Paterson (1986) who found that from 1850 to 1920 technological change was pervasively materials and capital using and labour saving. To address this point, David (1975) proposed that the labour-saving bias of technological change should be seen as a result of localized learning from an initial position on an isoquant chosen myopically on the basis of relative factor prices, as at point A in Figure 1a, a model based on an original idea by Atkinson and Stiglitz (1969). Although this localized learning would be neutral as shown in Figure 1b, its overall effect is to make the new isoquant (or FPF) shallower; that is, to change its slope in a labour-saving direction. Under nineteenth-century conditions it might also be argued that localized technological progress was more likely starting at point A rather than at point B. Then, it should also be noted that, while eventually sustained progress down the β ray but not down the α ray would lead to a point at which the α technology dominates at both sets of factor prices, the α technology might for a long time remain inappropriate for the country originally at point B (Broadberry 1994).

There is a big echo of the Habakkuk debate and, in particular, David’s contribution to it, in recent work on the British Industrial Revolution (Allen 2009, Broadberry and Gupta 2009). Allen (2009) based his interpretation of why the Industrial Revolution happened on international comparisons that show labour was very expensive and coal was very cheap in eighteenth-century Britain, and he calculated that it would not have been worthwhile to do the research and development (R&D) to develop several famous inventions in iron and textiles elsewhere – maybe this is best seen as induced factor substitution embodied in making available a new point on the APF in Figure 1a. It remains to be seen whether this interpretation becomes widely accepted. Broadberry and Gupta (2009) focus specifically on competition between British and Indian cotton textiles and see mid-eighteenth-century Britain at point A and India at point B in Figure 1a, from which starting point progress down the α ray is much faster and comparative advantage switches from India to Britain.

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7 Allen (2009) also stressed that, after some decades, further improvement in the technology (movement along the α ray) made adoption profitable in other countries.

8 Broadberry and Gupta (2009) argue that not only was much faster technological progress feasible down the α ray but that the patent system was more favourable to technological advance based on machines.
These analyses of the role of factor prices in technological change were developed through attempts to find theory to fit the facts. However, the theory menu has become richer recently, notably under the auspices of the endogenous-innovation school of growth economics such that Habakkuk-type arguments have acquired greater respectability and more is available to be adapted by future economic historians. In particular, Acemoglu

Figure 1 (a) Choice of technology: the role of factor prices. (b) Technical progress: localized change
Source: David (1975)
(1998) develops a model where the profits to innovation are proportional to market size because of fixed costs with the result that an increase in the number of skilled workers stimulates improvements in skill-complementary technologies, while Acemoglu (2009) contains a model in which labour scarcity promotes a faster rate of technological change given that technology is biased in the direction of being strongly labour saving.

2.5. Did late-Victorian Britain fail?

A debate that attracted many cliometricians in the early days of new economic history concerned whether there was a British growth failure in the last decades before World War I, the point at which the United Kingdom was overtaken by the United States. Allegations had been made by writers such as Landes (1969) that British firms failed to adopt new technology and savings were irrationally invested abroad rather than in new industries at home. Ultimately, the verdict of the cliometricians was that there was no significant failure. Generally speaking, decisions on the adoption of new technologies were based on sound profit-maximizing grounds (Magee 2004), foreign investment represented efficient portfolio diversification (Goetzmann and Ukhov 2006), while industrial structure reflected comparative advantage and maximized the level of income in a free-trade economy (Harley 2004). The overall verdict announced by McCloskey, even before all the evidence was gathered, was that the British economy was ‘growing as rapidly as permitted by the growth of its resources and the effective exploitation of the available technology’ (1970: 451).

Ostensibly, the cliometricians’ approach was fundamentally neoclassical, yet, on reflection, it was actually a precursor of the ‘appropriate technology’ view (Caselli and Coleman 2006, Jerzmanowski 2007) of international TFP gaps that is nowadays frequently invoked in North–South comparisons but was applied then to the leading economies of the time. The main reason that UK firms did not adopt American technology even though TFP in industry was much lower than in the United States (Broadberry 1997) was that they faced different cost conditions based on different factor endowments from those that had informed the evolution of American technology.

An interesting extension of this line of argument is that some American technology – for example, mass production in automobiles – was not adopted in Britain because the prevalence of craft-based trade unionism meant UK employers had less control of effort levels and worries about ‘hold-up’

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9 The difference being that the modern studies suggest that inappropriate technology is only part of the reason for lower TFP in poor countries since inefficiency accounts for a substantial proportion.
impeded technical change that required large sunk-cost investments (Lewchuk 1987). It should be recognized, however, that this was also a reflection of differences in the economic environment since American employers had much greater incentives to pay the price in terms of industrial unrest to eliminate craft control where markets were large and standardized (Haydu 1988).

The cliometric rejection of late-Victorian British failure relied on the neoclassical assumption that TFP growth was exogenous. The subsequent development of endogenous-growth theory suggests that this was unduly restrictive. TFP growth in the United States accelerated sharply from the late nineteenth century (Abramovitz and David 2001), leaving Britain well behind. A modern analysis would need to make clear why Britain could not match or even anticipate this acceleration. In principle, regarding TFP growth as endogenous delivers ambiguous implications for the exoneration of British growth performance. The United States had a much larger market and more human capital, which in some models would generate faster but not necessarily transferable technical change (Crafts 1998). On the other hand, questions might be raised about whether better UK policies – for example, in education – could have raised innovative effort in an economy that did little formal R&D.

Two points emerge from this retrospective on the Victorian failure debate. First, that detailed historical investigation at the micro level produced results that were incompatible with the usual neoclassical formulation of technological change as having a proportionate effect at all factor intensities. Second, the new economic historians’ exoneration of the British economy was based on strong assumptions that would seem questionable as economics changed in ways which took more seriously their own desire to explain innovation.

2.6. Social capability

For almost all countries, including those that do substantial amounts of R&D such as France, Germany and the United Kingdom, the main source of technological advance is technology transfer from abroad (Eaton and Kornum 1999). This places a premium on the ability effectively to assimilate imported technology both in terms of speed of its diffusion and realization of its productivity potential. In a very influential paper, Abramovitz (1986) emphasized that catch-up by follower countries was by no means automatic.

10 An intellectual strategy of which Abramovitz (1993) would presumably have been highly sceptical.
but depended on ‘social capability’; that is, having incentive structures based on institutions and policies that were conducive to these outcomes.

Abramovitz and David (1996) explained rapid catch-up of the United States during the Golden Age of European economic growth in the early post-World War II period as a result of increased ‘social capability’ and ‘technological congruence’ compared with the interwar period where a similar catch-up did not take place. Eichengreen (1996) saw the former as a result of the development of corporatist structures in some countries that delivered wage restraint in return for high investment. Abramovitz (1986) also pointed out that a country’s social capability might vary in different episodes of technological change. This is a comment that has considerable resonance in the context of the recent European productivity slowdown where the regulated corporatism that served many countries well in the Fordist-manufacturing era subsequently inhibited the exploitation of ICT (Crafts and Toniolo 2008).

The claim that institutions matter is, of course, characteristic of economic historians’ work on economic growth and development, most famously identified with North (1990) and Greif (2006). Here, since the mid-1990s, there has been a convergence between work on catch-up growth by economists and economic historians. Following the pioneering paper by Knack and Keefer (1995), it quickly became routine to include a measure of the quality of formal institutions in growth regressions and to find that it is economically and statistically important (Bleaney and Nishiyama 2002). Similarly, since Hall and Jones (1999), it has become widely accepted that low TFP levels in poor countries are to a considerable extent due to inefficiency that persists in the context of bad institutions.

There clearly are, however, important differences as well as similarities between these two literatures. In particular, there are four features of the economic-history work that have not yet been fully reflected in that of the economists. First, there has been considerable emphasis on the variance of institutional quality within the First World (both over time and across countries) rather than between First-World and Third-World countries. Second, it is important to note the influence of Alexander Gerschenkron in European economic history and his suggestion that latecomers required different institutions (and policies) compared with early industrializers. This has been especially influential in research in financial history, although ultimately empirical research has not been very kind to some of

11 ‘Technological congruence’ means that the technology was cost-effective in the follower countries; in terms of our earlier discussion, this translates into saying that the technology had become ‘appropriate’ as European relative factor prices and market size had changed. This anticipated a formal model by Basu and Weil (1998) that places appropriate technology in a conditional convergence setting with a ‘growth miracle’ phase as a possible outcome.
his claims. Third, the longer-run perspective of economic historians leads them to place more emphasis on informal or private-order institutions that are less amenable to quantification and the understanding of which requires game-theoretic analysis. Fourth, the new institutional economic history in the tradition of North stresses both the persistence of institutions and also the absence of any automatic tendency for good institutions to replace bad ones.

2.7. Path dependence (history matters)

The notion of ‘path dependence’ has attracted a good deal of attention in economic history. Path dependence is a property of non-ergodic stochastic processes whose asymptotic distributions evolve as a history of the process itself. So the vision of history is that in a multiple-equilibrium world it is possible to get locked in to a locally-stable equilibrium through historical accident. This may, but need not, entail market failure. By far the best-known example in the context of choice of technologies is the QWERTY keyboard (David 1985). To get too hung-up on this example would, however, be to miss the point. Certainly one aspect of path dependence is the choice between technologies. This was formalized by Arthur (1989) and, in principle, it is clearly possible that ‘historical accident’ can lead to a technology becoming completely dominant where standards with network externalities are involved (e.g., software) or where learning-by-using is important so that the not-necessarily inherently superior technology in which productivity improves through first-mover advantages in learning comes to dominate, as in nuclear reactors (Cowan 1990). But other aspects of path dependence relating to technology relating to institutions and geography matter more for cliometrics and tend to highlight the likelihood of divergence in economic development rather than the convergence predicted by traditional neoclassical models.

North (2005) has come to place a lot of weight on path dependence in institutional change. Once in place, institutional arrangements can develop network externalities and the support of the interest groups that they spawn. Reform may be vulnerable to status-quo bias (Fernandez and Rodrik 1991). Informal institutions are in any case not readily amenable to ‘top-down’ reform. Thus, ‘bad’ or outmoded institutions that arose through

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12 Notably, with regard to German banking, see Edwards and Ogilvie (1996) and Fohlin (1999).
13 The facts of this case, in particular the alleged superiority of the Dvorak keyboard, have been disputed by Liebowitz and Margolis (1990).
choices made long ago in different circumstances may persist. Institutions are central to ‘social capability’ and thus path dependence may be relevant to the international diffusion of new technologies and to their productivity payoffs (cf. Europe’s struggle with ICT).

Technological change may also be a factor in opening up the possibility of path-dependent outcomes. The new economic geography is replete with examples of this kind relating to industrial location where the trigger is a decline in transport costs. Krugman (1991) argued that the manufacturing belt became established in the United States when a combination of declining transport costs from the coming of the railroad with new technologies leading to increased plant size in manufacturing made spatial concentration of production attractive. The agglomerations that emerged were locked in by gains from proximity in trade in manufacturing intermediates.\textsuperscript{14} This is clearly a very different view of the world (and of the productivity gains from railroads) from that entertained by Fogel (1964).

Indeed, new economic geography models also embrace divergence in economic development as the processes described above involve industrialization in some parts of the world combined with (and part of the same process as) de-industrialization elsewhere (Krugman and Venables 1995). These arguments are theoretical but represent an important empirical challenge for cliometricians; is this what happened to Asia and Europe in the globalization of the nineteenth century?

3. What messages can economists take from the cliometrics of technological change?

Compared with the early days of cliometrics, the economics of technological change has evolved quite considerably. A number of issues that have always concerned economic historians but either were ignored or at least not well-handled by mainstream economists in the 1960s and 1970s have now been taken more seriously. Accordingly, to some extent the message is that there is potentially more synergy between the two research traditions. The review of key topics above indicates that the list of such issues would include endogenous innovation, factor scarcity as an influence on the bias and rate of technological change, the role of institutions in decisions to invest and/or innovate, and inappropriate technology as a reason for productivity gaps.

Nevertheless, there are still a number of important findings that are widely shared by economic historians but seem to be under-appreciated by many

\textsuperscript{14} Some empirical support for this argument can be found in Klein and Crafts (2010).
economists, indicating that traffic is regrettably still too skewed in one direction. These points can be gathered together from the previous section, as follows.

First, it is a big mistake to suppose that TFP growth equates to technological change. On the contrary, the evidence suggests that rapid TFP growth typically involves a substantial contribution from improvements in efficiency and that TFP gaps frequently owe a good deal to inefficiency. Moreover, growth-accounting datasets indicate that negative TFP is by no means uncommon sometimes for long periods of time, as in much of Africa in the last decades of the twentieth century (Bosworth and Collins 2003). This should not be construed as technological retrogression but rather as decreasing efficiency in the use of inputs.

Second, the essence of the Industrial Revolution was a substantial and sustained acceleration in the rate of technological change. A satisfactory analysis of the advent of modern economic growth must focus on explaining why this enhanced capacity for technological progress happened. Modelling this as a scale effect is to miss the point. Unfortunately, the first generation of unified growth theory did not take technological change seriously. Economics regards this work as important; economic history sees it as in need of a major re-think.

Third, big technological changes have modest impacts on aggregate productivity growth, especially initially. That was a key message of Fogel’s work on the railroads, which is well taken notwithstanding doubts about some aspects of his methodology. Likewise Crafts (2004), building on the work of von Tunzelmann (1978), concludes that the steam engine made virtually no difference to the rate of British economic growth in the classic Industrial Revolution period. This means that to an economic historian the paradox is that Solow’s ICT productivity paradox was regarded as such, given that by earlier standards the contribution of ICT in the late 1980s was already stunning.15

Fourth, economic history suggests that many economists are over-optimistic about the prospects for catch-up and convergence in poor countries. If institutions matter and need continual reform to achieve full catch-up, it is very possible that countries either get stuck in a low-level equilibrium (much of Sub-Saharan Africa) or find catch-up easy to start but difficult to complete (e.g. Japan). Thus, to followers of North, the

15 The so-called Solow productivity paradox relates to his much-quoted 1987 remark that ‘You can see the computer age everywhere except in the productivity statistics’. Article title: “We’d better watch out”, New York Times Review of Books, July 12, 1987, p. 36. A great deal of effort was devoted to explaining this (Triplett 1999), but according to Oliner et al. (2007) the contribution of ICT to American labor productivity growth averaged 0.74% per year during 1973 to 1995.
neoclassical prediction of future convergence of incomes appears to be very optimistic even though enthusiasts argue that, now it is understood which institutions and policies are conducive to growth, in a globalized world rapid catch-up growth financed by capital inflows should be much easier to achieve (Lucas 2000). Similarly, the projections of future catch-up by the so-called BRICs economies that have been popularized by Goldman Sachs (Wilson and Purushothaman 2003) have a mechanistic flavour that abstracts from the political economy of development.16

4. Conclusions

Technological change is a key area of cliometric research. The questions that are posed by economic historians have always been ambitious and the range of experience that has been investigated is very wide. This has meant that on many occasions what economics has been able to offer the economic historian has been limited and potentially very limiting. Some questions are still too difficult; for example, explaining why the Industrial Revolution happened. Technological change is an area in which it would seem to be particularly unfortunate to believe that writing neoclassical economic history is enough.

It should, however, be recognized that, since the early days of cliometrics in the 1960s, there have been important innovations in economics which make the use of economic analysis less restrictive. More of the intuitions of economic historians can be and have been formalized, for example, in the areas of endogenous innovation and economic geography, and so are taken more seriously by economists. And in important ways, most notably in reaching a consensus that institutions matter, economic history and growth economics have found common cause with greater possibilities of two-way trade.

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References


16 BRICs is an acronym for Brazil, Russia, India and China.


This paper considers the approach to technological change by quantitative economic historians. It suggests that there has been a continuing tension between what economics has to offer economic history by way of technical methods and what economic historians would like to find in economic models. In this area, there has been a danger that use of economic analysis would impoverish historical enquiry. Since the advent of new growth economics the situation has improved in the sense that there is now greater congruence between the hypotheses proposed by cliometricians and the resources that economics has available to them to investigate these ideas rigorously. Unfortunately, however, economists are still reluctant to learn from economic historians.

**Keywords**

Cliometrics, economic growth, technological change, total factor productivity