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HISTORICAL COEVOLUTION OF GOVERNANCE AND TECHNOLOGY

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(diagrams not available)

My brief for this contribution to 'The Future of Innovation Studies' was basically – and somewhat perversely – to look back to the past. I have interpreted this as a call to consider what key issues from the historical record still remain outside the purview of the recent radical redesign of innovation studies. The issue – chosen from a potentially large list of candidates – that I have decided to re-examine is the historical coevolution of governance and technology. The reasons for my choice should become more evident as I proceed, though two points should be made at the outset. First, I do not claim that this has been ignored in the innovation studies literature – the question of the links between technological change and organizational change, for instance, is a very standard one, and moreover scholars such as Richard Nelson (2001) have paved the way for reinterpreting the development of governance as well as technology. Yet I believe it is still fair to claim that the interrelationships between governance and technology have been either largely overlooked or found somewhat intractable. Second, I do not by any means claim to be able to solve the nature of these interrelationships within this paper. Instead it is intended as a plea to place the issue on our agenda. More precisely I perhaps should suggest placing the issue back on our agenda, as in classical political economy as handed down from Adam Smith the issue lay at the centre of their analysis.

The paper takes a highly macroscopic view of long-term change. This should not be regarded as implying that I believe that to be sufficient. On the contrary, it is the constant interaction between the macroscopic and the microscopic which underlies historical evolution and revolution. The microscopic aspects however are being developed in other associated work and must be largely glossed over here.

Defining governance

One of the undoubted problems with any such analysis is that of defining what we mean by 'governance' – a fashionable but often elusive term. It may be helpful to set out what I intend to include within the scope of 'governance'. I regard – following the work of a number of scholars – as comprising issues of structure, control and process. Of these, I do not say much about process since it appears to me to deal predominantly with immediate rather than

substantive issues, though there are major scholars whose analyses depart from processual views and with whose views I probably need to engage better. In the absence of so doing, this leaves me with matters of structure and control as the constituents of governance pertinent to what I shall be covering. These in turn can be defined in a multitude of ways, but I think it is enough to regard 'structure' as being about the forms through which decisions are made and 'control' as about the power to make those decisions via such structures. The decisions themselves can of course cover every kind of activity in principle, but for obvious reasons I limit myself here to economic decisions – that is, decisions about production, distribution and exchange.

The recent literature has come to identify the 'ideal types' of governance modes as markets, hierarchies and networks (e.g. Thompson et al., 1991). Hierarchies need to be separated as between corporate hierarchies, i.e. large firms, and political hierarchies, i.e. states. The key debate – one might call it 'battle' – in the literature is which of these best serves the purposes of achieving development and prosperity. As we shall see, this battle is somewhat illusory as there are in practice interdependencies as well as conflicts between the various governance modes, and in practice all systems are hybrids. As it stands, the 'battle' is usually fought out in a rather negative fashion, by focusing on the alleged deficiencies of each mode. Thus we can speak in terms of market failure, of corporate failure, of government failure, and indeed of network failure.

Theories of governance

There are at least six theoretical approaches to governance which can assist our inquiry. These are difficult to compare since they originate in different disciplinary perspectives, but all turn out to be of some use here.

- 1) 'Economic governance' theories categorise modes of governance mostly between markets and (corporate) hierarchies, with some oblique reference to networks as hybrids of markets and hierarchies. The basis is transaction cost economics and neoclassical economics more generally, and the stance is generally static, though some dynamic generalisations have been suggested. Issues of power and the state are explicitly avoided.
- 2) 'Public choice' theories, as an extreme version of neoclassical economics, see the state as no more than a collection of profit-maximizing individuals or lobbies. It is assumed to have no collective adhesion to act in the national interest. 'Government failure' is presumed. While this may seem an extreme position, it does underline that we need to explain how it is that a state could indeed come to act in the national interest, a key point in what follows.
- 3) 'Political economy' theories contrast states and markets, largely leaving firms and corporate hierarchies out of the picture. The predominant emphasis is on 'market failure'. This approach can readily be linked to the 'national systems of innovation' literature in the economics of innovation, because of the primary role of the nation state.
- 4) 'Political governance' theories have been developed mostly by political scientists and sociologists, following the tradition of Max Weber. It shares with the 'national systems of innovation' literature a strong emphasis on the role of intermediaries and networks. The general emphasis has however been on 'sectoral systems of governance', arguing that different sectors such as IT or automobiles have characteristics which transcend national boundaries, and are specific to that sector across many countries. In this they link more closely to the Swedish school which emphasises sectoral systems of innovation.

5) 'Regulation' theories overlap with these political governance approaches, though with more input from economists and in a different national setting (French rather than US/German). The emphasis lies on the 'tuning' between different types of hierarchies, including factors of production (labour and capital) as well as corporate and political hierarchies. The 'social systems of innovation' perspective which grew out of this takes an enlarged view of innovation systems and comes very close to my approach here, but has been adopted in only a small number of studies (Amable et al., 1997).

6) 'Institutionalist' theories, especially in the form recently reworked by Douglass North, draw attention not only to the role of 'institutions' – which are differentiated from 'organisations' and consist of e.g. ownership systems or monetary systems – but also to the interdependencies with various modes of governance. Thus North stresses that markets did not exist in a vacuum, but were the product of, among other things, the active encouragement by states. The counterposing of states versus markets in a historical setting is thus somewhat specious.

Indeed the point may be made more generally, that the interlinkages among supposed sources of failure are too widely ignored. The 'market failure' argument for government intervention, which has been much used to sustain the intervention of neoclassically-bounded organisations such as the World Bank, presumes that government intervention will fix the market failure, but there can be no such presumption. The 'government failure' argument that the state should retreat and leave everything to markets, so powerful politically in the restless years of the 1980s, is equally deficient (Chang & Rowthorn, 1995). We need deeper exploration.

Revolutions in governance

The historical experience of contrasting modes of governance reflects this diversity of theoretical perspectives. The predominant literatures have emphasised the evolution of hierarchies, both corporate and governmental. The evolution of markets and the evolution of networks have been given far less attention, and in my view much less than their due. I shall come back later in the paper to the evolution of networks, but for the time being I shall stick with the mainstream and chart the evolution of hierarchies, especially corporate hierarchies.

The orthodox way of envisaging this evolution is of depicting three phases of ideal types of corporate hierarchies. The first phase, of 'personal capitalism' or 'proprietary capitalism', consisted overwhelmingly of small producer firms, launching the industrial era. Decisions were made, or at least reconciled, through the exercise of Adam Smith's 'invisible hand', i.e. markets. The second wave consisted of the dominance of large corporations and thus 'corporate capitalism', occurring about a century after the first phase. Here decisions were effected through what Alfred Chandler (1977) called the 'visible hand', i.e. of management. The third phase is more contentious. Most views appear to accept some kind of characterisation of 'network capitalism', though in differing ways. The 'Second Industrial Divide' perspective of Piore & Sabel (1984) supposed this to be a return to small enterprises, albeit networked in industrial districts. Others pointed to interactions between large firms and small firms, or among the large firms themselves. Depending on which one chooses one might come to different conclusions about dating this phase. Since it is not my primary concern in this paper in historical terms, I propose to lump some of these together here and think of 'network capitalism' as coming about again about a century after the second phase of corporate capitalism. For the moment, we can think of its key characteristic as a phase in

which external links among companies became as significant as internal links within each of them.

In other words, we can suppose the successive predominance of markets, corporations and networks in the evolution of corporate governance. These phases or waves of corporate governance types were marked by revolutionary discontinuities as each emerged ('revolutionary' here does not mean abrupt, but radical). Even the first phase of small market-led firms can be seen as a revolutionary departure. Adam Smith's *Wealth of Nations* was a call to reaction against the power of large monopolies (and countries) controlling the distribution side of the economic coin, and thereby controlling production and exchange as well. His primary political goal was the overthrow of 'mercantilism', and the power of large companies that he saw as 'conspiracies against the public'. Paradoxically, therefore, large companies preceded as well as followed small firms in the industrial era, though the predecessors were distributors while the successors were producers.

Cutting across these temporal patterns of evolving governance were what some see as distinctive national patterns – what we might term 'national systems of governance'. This is the basic message of Chandler's view of business history, of which he has been the key architect. In *Scale and Scope* (1990) he makes national differences the central issue, with 'personal capitalism' seen as an attribute of Britain, 'corporate capitalism' as one of the USA, while Germany experiences 'collective capitalism' as something of a midway position. In his view these national characteristics have much to do with failure and success in long-term business development; specifically, the US 'corporate capitalism' based on the exercise of the 'visible hand' is regarded as the epitome of industrial success.

Critics – among whom I would count myself – found much to oppose in Chandler's stereotyping of national systems of corporate governance, quite apart from the underlying whiff of American triumphalism. Cassis (1997) and others conducted more detailed historical analyses to show that Britain did not lag anywhere like as far behind the USA in building large corporations as Chandler supposed, and certainly moved sooner and further in this direction than Germany. Moreover, at the time he was writing, when American industry appeared to be failing in its confrontation with Japanese industry, the rejection of 'collective capitalism' appeared incongruous. His view that the entrenched large corporations would win out over new entrants such as Microsoft, because physical capital would come to accommodate technological capital, appeared to be losing ground. However maybe, in the aftermath of the last decade, he may yet have the last laugh, as for instance reflected in the recent takeover of Compaq by Hewlett-Packard, and more generally the resurgence of the American economy. Whether American capitalism still fits his description of it may however be questioned. Of still deeper concern here is his virtual neglect of technology issues in his stylisation of corporations as being 'three-pronged': manufacturing, marketing and management (von Tunzelmann, 1999).

Nor does Chandler at all engage with the role of government and of political hierarchies, but in this he is of course far from alone. Nevertheless it is an important part of our story. The recent re-examination of the cotton industry by Rose (2000), tracing its comparative development in the UK and US, emphasises the much more collective attitude to business activity in the US – the supposed archetype of individual liberties – from the earliest days. Much of this was based on local communities, but included a major role from earliest times for state and local government in the various regions of the USA (which differed sharply from one another, cf. North, 1961). State and local governments led the way to incorporation

through themselves setting up public utilities, redistribution agencies, educational institutions and the like on an incorporated basis, before the first incorporated private companies. The rejection of incorporation in the context of the overthrow of mercantilism in the UK provided a sharp contrast, notwithstanding the similar legal systems and indeed common heritage of the two countries.

Rose suggests that this might be seen in the light of an adapted Gerschenkronian view of the USA as a catching-up country in the early nineteenth century, following in the wake of the British industrial revolution. In sharp contradiction of recent views that development is best 'left to the market', Gerschenkron (1962) contended on the basis of comparative history that states would be more involved, the later the catching-up process was left – the extreme in his studies being the case of the Soviet Union after 1917. Arguably this could be replaced by the view that this applied mainly in the phase when hierarchies prevailed, allowing substitution between corporate hierarchies and political hierarchies in the development process. In the third wave I have described, a more interactive role for the state would seem to be called for, and this seems highly consistent with current thinking. It should also be noted that Gerschenkron draws attention to differences in banking/financial systems and technological choices according to the level and pace of catching-up. The former is fully consistent with an early Schumpeterian view of the role of credit systems in times of 'abnormality' (Schumpeter, 1934).

I turn to technological changes in a moment, but before that I wish to underline that, in terms of governance modes, all major structures existed in all leading industrial countries to significant degrees throughout the modern industrial era. To be sure, the particular controlling system varied both through time and to a degree across countries via the various 'national systems of governance'. But not only did all play some role, often they complemented one another, as with incorporation at the government level sponsoring incorporation at the private level in the US. In a transaction cost perspective, contracts are seen as essential in order to avoid the opportunism deriving from a reliance on trust, but in practice contracts often depend on trust and conversely (Dyker & Turk, 2001). As North (1990) argued, markets, too, depended on prior actions taken by governments to underpin them, including the development of property rights. Again, the either/or view of modes of governance is difficult to support.

Revolutions in technology

The phases of technological growth have been more clearly delineated in the literature, particularly in the long-wave literature (e.g. von Tunzelmann, 1995, 1997a; Freeman & Louçã, 2001). The simplest formulation is that which demarcates three 'industrial revolutions'. The First Industrial Revolution took hold in Britain towards the latter part of the 18th century, the Second Industrial Revolution arose in Germany and especially in the USA in the later 19th century, while the Third Industrial Revolution emerged in a variety of industrialised countries in the later years of the 20th century. There is some dispute, not just over the precise dating of these 'revolutions', but also over their number and heterogeneity. The long-wave specialists such as Freeman think in terms of Kondratiev cycles and would propose five or maybe more Kondratiev waves in the industrial era, lasting an average of about 50 years rather than 100, so only the odd-numbered long-waves count as industrial revolutions.

Serious investigation of this debate would take me somewhat away from my main topic today, but some issues are germane. The long-wave view as articulated in papers and books by Chris Freeman anchors those long waves in specific technological breakthroughs. The alternative view, which I espouse, sees the technological breakthroughs as critical but not the only issue in discussing industrialisation more broadly. The industrial revolutions are characterised by an initial sub-phase of these breakthroughs, initially narrowly focused in both technological and sectoral terms – what Rostow (1960) referred to as ‘leading sectors’. Often the development in this sub-phase consists of trying to produce old products using the new processes, as a kind of technological substitution. In the fullness of time, two things happen: new products and areas of application emerge and become diffused, and the range of applications spreads to other sectors, even some of the ‘traditional’ sectors, partly through the rise of these new product applications. In this view, the even-numbered Kondratiev waves – those beginning around the 1830s (the second Kondratiev), the 1920s (the fourth), and hopefully – for the sake of rescuing the global economy – the 2010s (the expected sixth) – represent applications of the core technological breakthroughs set up in the preceding odd-numbered Kondratievs. Thus the fourth Kondratiev of ‘motorisation’ represents the product application of the technologies of internal combustion and metallurgy initially developed in the third Kondratiev (to motor vehicles etc.). And so on.

I have noted the theoretical bases of this view in several papers (e.g. von Tunzelmann, 2000). Two sources are especially important – one is the notion of ‘innovative choice’ developed by Amendola & Gaffard (1988) based on Hicks’ neo-Austrian notions of the roundaboutness of capital, here applied to intangible (technological) capital; and the second is the recent more applied studies of ‘general purpose technologies’, by Helpman (1988), Bresnahan, Lipsey and others. The implications for today’s more historically oriented paper take me in a somewhat different direction.

The downside of taking a ‘three industrial revolution’ rather than ‘five/six Kondratiev wave’ interpretation is that technological breakthroughs have to be bundled together, even where their origins were very independent and not necessarily exactly coincident in time. I have described elsewhere (e.g. von Tunzelmann, 1994) how the key paradigms of Britain’s First Industrial Revolution came very different origins – mechanical technologies representing the outcome of a drive towards speeding up processes especially in textile production, while steam power was developed to meet the needs of mining for access to deeper and deeper beds of coal and metallic ores. These very different products of the manufacturing sector on the one hand and the mining sector on the other fused into the steam-mechanical technologies evolved as the key production process in textile and other factories as early British industrialisation matured towards the emergence of the second Kondratiev wave around the 1820s. Similarly the Second Industrial Revolution involved roughly contemporaneous developments in electricity, chemicals and internal combustion engines, again with no immediate interlinkage although with some traits in common. The Third Industrial Revolution appears to have been launched out of electronics through the transistor and integrated circuit, supplemented by the rise of ‘third-generation’ biotechnology based on recombinant DNA and cell fusion from 1973 – the fusion into fields like bioinformatics again a much later phenomenon. The independent origins of these multiple breakthroughs give some credence to a more frequent cyclical characterisation than ‘industrial revolutions’, such as the Kondratiev wave, but equally on historical grounds they follow each other too quickly to meet the Kondratiev criteria in my opinion – perhaps we need to resort to shorter cycles such as the 20-year Kuznets cycle to locate them better in chronological terms. The long-wave tradition does however help us in identifying the multi-faceted nature of industrial

revolutions – the fact that they spanned and coalesced motive technologies (steam/electric/oil), material technologies (iron/steel/silicon), communication technologies (telegraph/telephone/internet), transportation technologies (rail/automobile/aircraft), handling technologies, construction technologies, as well as the succession of technologies more obviously related to production process and to product. Indeed this cross-cutting of technological advances deserves more attention than either historians or evolutionary economists have presently given it.

The second point here is to conclude that, when taking this sort of broad historical sweep, the launch phases of industrial revolutions are characterised by the primacy of process innovation. Steam-mechanical technologies supplied the motive and manipulative processes for the First Industrial Revolution and for its imitators in many other early industrialising countries – countries such as Italy without the resources to fuel these technologies were for the time being left behind. At first these were applied to substituting for existing processes, in this case basically labour-intensive hand or craft labour, on existing products. But as these ‘general purpose technologies’ spread to new applications, a range of new products followed in their wake, in ways I have already briefly touched upon. Hence industrial revolutions involved first a revolution in processes and then a revolution in products. It will be noticed immediately that this contradicts two stylised models of the literature.

The first is the ‘product lifecycle’ approach popularised by Utterback (Utterback & Abernathy 1975; Utterback, 1994), which clearly asserts that product innovation precedes process innovation. The present viewpoint indeed has more in common with Richard Barras’ ‘reverse product cycle’ (Barras, 1986, 1990), where he argues that the pattern in financial services involved adopting processes from manufacturing that were to lead on to new types of financial service products. The difference is that here I argue this to be the norm rather than the exception – the Barras formulation becomes simply a characteristic of the spread of GPTs. Why should the traditional product-process sequence work at the level of industrial revolutions? A number of reasons can be suggested, but perhaps the key point is the question of the relevant unit of analysis. Indeed Utterback & Abernathy make this point explicitly in their original paper, that the choice of unit of analysis is critical – in practice, however, their papers wavers between choosing the firm and choosing the product as the unit of analysis. If the product is the relevant unit, then it is easy to see why the product-to-process sequence will appear to occur – effectively because the issue of where the new product comes from (say the motor car) is never addressed. Competitive forces at the micro level drive the model.

The second stylisation is more associated with economists, though it follows a parallel path. In models attempting to capture the sequence of innovation and imitation at the national level, the kind of neoclassical model postulated by Krugman (1979) and generally known as the North/South model reaches a similar set of conclusions. Innovation begins in the North, which evolves new products. Countries of the South subsequently copy those products, which they produce on the basis of low-wage processes, and therefore undercut the Northern producers. The Northern producers are then pushed into a further wave of innovation to supply newer products in which they can maintain their lead (for a time). Again, it is product innovation which inaugurates the sequence. It is quite different from what scholars such as Hobday (1994) have found for the Asian Tigers, where the observed sequence involved developing better processes to produce initially imitated products, thus leading Hobday also to posit the ‘reverse product cycle’ as the more apt description. It should be noted that evolutionary as well as neoclassical scholars have pursued the product-process sequence of the conventional North/South kind, for instance in the book by Dosi, Pavitt & Soete (1990).

Actually I argued in my 1995 book that long before, in the mid-18th century, the Scottish philosopher and friend of Adam Smith, David Hume, had presented the same model (for catching-up in European countries). Competitive forces at the macro level drive this model.

Going back to the threefold industrial revolutions, it can be seen that the process breakthroughs, which marked their emergence, differed in terms, not just of the specific technologies, but more generally in terms of the key resource to which they related. In the First Industrial Revolution, the key resource remained the labour. To be sure, that labour force was now equipped with steam-driven complex machinery, but that is probably the way to see it – as machine-assisted labour. As Lazonick and indeed long ago Karl Marx insisted, it is the labour process, which needs to be analysed to understand the nature and the evolution of production. More controversially, Lazonick (1992) goes on to contend that it was adherence to increasingly outdated labour processes that led to Britain being eclipsed by the USA during the Second Industrial Revolution. Marx in the *Grundrisse* (1857/8) noted that even in the British Industrial Revolution, labour processes were losing way to capital processes as industrialisation proceeded. Nevertheless I believe it is reasonable to claim that it was only in the Second Industrial Revolution that the key characteristic became capital process, because in this stage of mechanisation and automation it became more appropriate to talk of labour-assisted machinery rather than machine-assisted labour. The frantic worker caricatured by Charlie Chaplin in *Modern Times* (1936) captures this phase, when Fordist-Taylorist work patterns came to prevail. The many successive stages by which mechanisation (the automation of ‘transformation’) developed into the automation of ‘transfer’ and in more recent times the automation of ‘control’ were set out by Bright (1958) and later Bell (1972). In the Third Industrial Revolution, information processes partly linked to this automation of control appear in turn to be supplanting capital processes, stemming of course from the launchpad of initial technological breakthroughs in information and communication technologies. It is a shortcoming of my 1995 book that I failed to identify the shift from capital process to information process at the heart of production transition.

A further implication of this view of historical sequence I am advancing is that technology growth follows a different pattern over time from productivity growth. In neoclassical economics, the two are equated at least up to the point where productivity growth is often assumed to be the measure of technology growth. This equation of technology with productivity stems from the reductionism implicit in the neoclassical production function. It is not suitable for longer-term historical analysis. The productivity impact of newly emerging technologies is often very limited – the technology remains quite crude, the extent of application is very narrow, and the costs of development are very high and normally rising. All industrial revolutions are thus associated with comparatively slow productivity growth during their technological revolution stage. Recent work has emphasised the slow growth of Britain during the heyday of its industrial revolution, only turning the corner when moving into what Freeman would see as the second Kondratiev wave about half a century later. Similar evidence can be provided for the USA in the early stages of the Second Industrial Revolution, where extensive growth was much stronger than intensive growth, which came later alongside the drying up of large-scale immigration following World War I. One of the characteristics of what I am regarding as the Third Industrial Revolution is the so-called ‘productivity slowdown’, but on this argument a period of slowdown in productivity is just what would be expected alongside the emergence of dramatically new technologies. For a historian there should be no puzzle about the ‘productivity slowdown’, which has largely arisen in my view for similar reasons as in the two previous industrial revolutions – it is only

a puzzle for those expecting to equate technology growth with productivity growth, when they are really two different animals.

Another way of making this point is to contend that technological breakthroughs are not enough to ensure sustained growth and development. This leads me back to my main theme today.

Causal links?: revolutions in governance and revolutions in technology compared

We conclude there have been three main eras in governance during the industrial era – marked successively by the predominance of markets, corporate hierarchies and then networks – and three industrial revolutions, spanning multiple technologies but originating in the successive predominance of labour processes, capital processes and information processes. Moreover, these three phases of each domain seem to have arisen at roughly similar times, namely the mid-to-late years (say third quarter) of successive centuries, though the demarcations are less sharp in regard to governance than to technology. We now therefore turn to the central issue of the potential linkages between these contemporaneous phenomena – the possible sources of their coevolution.

Given the way I have so far put the arguments together and applied my own criteria to defining the phases it may be thought that we are already at least halfway to answering why the two coevolve, but the issues are not quite that simple, and certainly historians have not seen them as such. As the statistical cliché has it, correlation does not necessarily mean causation, and there has been some effort spent on looking for causal links – though perhaps not nearly as much effort as one might expect.

One dimension this has taken is to look for precedence in time – which came first, the governance changes or the technological changes? One obvious difficulty with this is that dating is practically impossible, since unless one is taking a purely antiquarian perspective of looking for the very first occurrence – which is generally far from helpful as first instances were often hopelessly unsuccessful or off-target – it is problematic to judge when one or the other revolution became viable. We can search for early instances of cross-causation, which is what I did in my own doctoral work (von Tunzelmann, 1978) on the origins of the steam-mechanical paradigm, and where I found that none of the earliest textile machines associated with Britain's Industrial Revolution (spinning jenny, mule, water frame, power loom) was first driven by steam power – their first appearances were driven by hand, animal or later water. Hence I could try to reject the view that steam power 'caused' the appearance of innovative machinery as a major 'forward linkage' (steam was later recruited to drive the already evolving machines). However this becomes more problematic when trying to trace the initial causal links between governance changes and technological changes. In this First Industrial Revolution there are instances of almost every conceivable pattern. There were technological changes introduced into traditional governance forms, like the 'cottage factories' for silk in Coventry, supplying steam power to private homes. There were governance changes in regard to traditional technologies, like the handloom-based 'weaving sheds' in Lancashire textile mills. There were precocious cases of very early corporations introducing new machinery which went spectacularly bust, like Lombe's silk mill at Derby in 1777 – or perhaps the dot.com companies of recent times.

The debate has therefore concentrated to a greater degree on orders of importance. Have the changes in governance been more or less important than the changes in technology? The implication of Chandler's approach to business history noted above is indeed to imply that governance changes (in management etc.) are the more important, as well as preceding in time. However this is achieved, as I have stated, by mostly suppressing technology as a separate issue. A comparatively recent example of this sort of debate, in regard to the First Industrial Revolution, is one between Stephen Marglin and David Landes over which was the more potent symbol of that revolution – the factory, interpreted as a governance mechanism, or the machinery? Landes' original survey (Landes, 1969), drawn on his background in entrepreneurial history, had suggested a combination of technological and cultural factors explaining why Britain came first and why it later dropped behind. Marglin (1974), from a background in radical economics, instead took a strong labour-process view, in a paper entitled 'What Do Bosses Do?' For him it was the control entrusted to the 'bosses' through the factory system that crucially defined that Industrial Revolution. Landes (1986) replied with a restatement more strongly favouring the technology as the *sine qua non* of early industrialisation. Both sides could accept some interdependence between governance changes and technological changes, but remained committed to their respective views about priority.

It turns out that this, however, was only a later stage of a long debate, which had mostly taken a somewhat different direction. More detailed historiography revealed that throughout there has been a tension among historians between those conceiving that organizational changes (centred on the factory system and how it operated) or instead technological changes (centring on mechanisation) were the most defining characteristic of the British Industrial Revolution. The Landes-Marglin debate was only the latest surfacing of a much older controversy (Cannadine, 1984; von Tunzelmann, 1985), and as that latest occasion demonstrated, there was much more to it than the obvious interdependence between factories as plant and machinery and equipment within the plant. Indeed when the term 'Industrial Revolution' was first popularised in Britain (it had been 'invented' by an earlier French scholar), by Arnold Toynbee's *Lectures on the Industrial Revolution*, first published in 1884, it was as referring to the factory system, not the technology within it. In fact two traditions emerged, one pursuing what we would now call the revolution in governance, the other the more tangible revolution in technology.

Historians were notoriously poor at defining their terminologies, but it has become evident that the former were (implicitly) studying Capitalism, while the latter were studying Industrialism. They engaged in protracted and tortured debates with one another, often without realising that they had different things in mind, and indeed often supposing the two were effectively synonymous. But as my preceding discussion shows, they were by no means necessarily coincident, much less synonymous. Industrialism could progress without Capitalism, as famously the USSR tried to achieve after 1917, conversely Capitalism could proceed without Industrialism, as it does today in the Cayman Islands. Capitalism is notoriously short of adequate definition, but to try to clear the air, in my 1985 paper I defined capitalism as a system in which control was exercised by those who owned capital. In terms of the theoretical perspectives defined earlier, it consists of a proposition in political economy rather than industrial or organizational economics. The period of the British Industrial Revolution was one that witnessed a power struggle between large agricultural capital and emerging industrial capital, crystallising in the famous debates over the Corn Laws. David Ricardo, who made his money from finance and ended life as a wealthy landowner nevertheless took the side of industrial capital, while his friend Robert Malthus – a none-too-wealthy rural parson – took the contrary side of agricultural capital. The debate ended in the

Repeal of the Corn Laws, the coming of free trade, and the victory of the Manchester-based industrialists. It was however quite a short-lived triumph, because as Britain slipped behind in the years of the Second Industrial Revolution to follow, industrial capital was supplanted by financial capital as the dominant force in the UK, and indeed throughout the 20th century it was finance capital that ruled the UK's national economic system, never more so than under Mrs Thatcher in the 1980s.

These contrary kinds of 'capitalism' – agricultural and financial as well as industrial – further reveal how Capitalism and Industrialism do not coincide, and we still need to explain circumstances in which they do. In attempting to do so, I revert to evolutionary theory in which innovation studies is more at home. The intention is to unpick how the notion of evolution applies, with the aim of getting closer to accounting for coevolution.

Evolutionary theory of technology

To the present audience there is no need, I think, to give an extended account of the evolutionary theory of technology. Whether we buy the package as a whole, or only parts of it, or indeed little of it, we cannot avoid encountering it. Let me therefore make a few rather ancillary and more historically oriented points about it, as shaping the much fuzzier discussion to follow.

I draw on Giovanni Dosi's very useful transliteration from the philosophy of science into the analysis of technology, by which the evolution of technology can be understood at the successive levels of paradigm, heuristic and trajectory (Dosi, 1982). The notion of the paradigm in the way I apply it – which has no necessary relationship to the way Dosi might like to apply it – combines the two kinds of issues explicit in the word 'technology'. The '-ology' suffix denotes an area of analytical understanding, or 'know-why', drawn from basic science or engineering, for example Newtonian mechanics or genomics. Such understanding may not be codified and indeed may often be based on scientifically invalid propositions.; a fortiori I do not mean to imply any necessary 'linear model' by which scientific advances move downstream to become embodied in technical advances. It reflects no more than a deeply perceived understanding which happens to work well enough for present circumstances, even if it turns out to be mistaken in more general circumstances. The 'techn-' prefix obviously connotes some sphere of practical application, which makes the general '-ology' understanding sufficiently concrete to work with in historical conditions. Thus in my view, steam power is a technological paradigm, involving the '-ology' of energy provision – indeed a historically celebrated case in which the science and engineering of thermodynamics arose out of trying to explain the performance of the steam engine rather than the linear-model reverse – and the 'techn-' of the specific form of the steam engine, whether used for pumping water out of coal-mines or driving textile machinery in factories or propelling locomotives on iron rails, etc.

If the broad area of technological application is given by the paradigm, the forces which in general terms drive the technology forward, or prevent it from being held back, are given by the heuristics, positive or negative. The dominant heuristics in my previous analyses have been the underlying physical constraints of time and space. The evolution of information and communication technologies in the modern era is exemplary. Miniaturization was the prevailing heuristic for the 'motors' of the ICTs, namely the transistors and integrated circuits produced from semiconductor technology. Originally spurred by the need to compress size in

order to be accommodated in early satellites, when they moved into commercial application the miniaturization heuristic was seen to gain economies not only in space but also in time, i.e. working much faster because of being so much smaller (Swann, 1986). 'Moore's Law' presented rule-of-thumb guides as to the pace of this progress. However economies of speed were equally potent heuristics for both the First and the Second Industrial Revolutions. Chandler's account of the driving forces of speed-up in both production and distribution in the emergence of 'big business' in late 19th century America remains a classic study (Chandler, 1977). In all of these cases, the negative heuristics flagged ways in which scaling-up processes (Sahal, 1981) had to avoid impracticality while in pursuit of their objectives – an issue that becomes clearer when we turn to the third level of the trajectories.

Economies in time and space allow us to relate technological change to conditions of demand as well as the more usual conditions of supply. Rising demand in quantity terms put pressure on the producers to produce more in each period of time from their existing physical capital (plant and equipment), and hence to speed up. Rising demand in quality terms generally meant achieving higher qualities of product without running into sharply diminishing returns from approaching the limits of existing human or physical resources. In both cases, demand and supply needed to be coupled. A case in point is the food industry of recent times, both in manufacturing and services. For cooking services, consumers have switched to buying readymade meals in supermarkets (which themselves can be seen as space-saving and time-saving) and to buying from fast-food restaurants, often I imagine sacrificing quality for speed in consumption by so doing. The manufacturers need to produce and especially test the quality of food in real time, for which they are recruiting radically different technologies aimed at speeding up the quality testing process.

There is however a potential trade-off between quantity and quality. In regard to the quality dimension, different countries have selected very different heuristics. On the one side, the historical record suggests that, once enough countries are taken into account, the scale-and-scope dimensions are little related to growth and development. Neighbouring countries like Taiwan and South Korea could make quite different choices about scale and scope of their enterprises, yet achieve quite similar economic and developmental performances. However the choice of product quality and especially process quality appears to have a more direct bearing on growth performance. Some countries choose a product quality strategy during their development process, e.g. France or Italy, others more of a process quality strategy, e.g. East Asian countries. Either can achieve satisfactory growth given the right conditions, though there is usually a 45-degree line of tradeoff (von Tunzelmann, 1997b). Rapid growth can come about where process quality is interlined with reasonable product quality, as the Japanese case suggests. Lack of growth ensues, of course, when neither exists, which all too many countries experience.

The precise 'trajectories' followed by the evolving technologies thus usually reflected the interaction of a surrounding context of economic and social factors. For instance, although it is widely supposed that technological change follows a labour-saving heuristic, in fact it is often only at the trajectory level that labour-saving (or the saving of other factor inputs) arises. That is, a given time-saving change in a certain technology may often be oriented to saving labour in a labour-constrained environment while extensible to saving capital in a capital-constrained environment. Much of the adaptations made by the Japanese to inward technology transfer during that country's early developmental phase were of this kind. The Americans and the Chinese both use time-saving procedures for building shopping malls in

rapid time, but the techniques in the US are much more labour-saving than in the labour-abundant Chinese economy – if anything, however, the Chinese build even more quickly.

One of the key features of technological accumulation through time is its heterogeneous nature. The successive industrial revolutions add new areas of technology to the industrial armoury, but they take few away, at least at the ‘-ology’ level. So the First Industrial Revolution can begin with advances limited primarily to energy, mechanical and material ‘know-why’. The Second Industrial Revolution changes the paradigm within these arenas – from steam power to electricity and internal combustion, from iron to steel, etc. – but also adds new arenas to the heartland of industrial activity, such as chemicals. The Third Industrial Revolution adds biological technologies and ICTs to the industrial core. True, none were the first exemplars of their technological field – both biological and information technologies can be traced back in some form to prehistoric times – but it was at this stage that they became central to industrial activity. Each new arena added not just itself but also (subsequently) some interdependencies, such as the electrochemical and electromechanical technological fusions of the early 20th century. In these senses, technologies became more complex – deeper levels of ‘know-why’, broader levels of cross-linkage.

Heterogeneity applies also across space as well as through time. As new countries arose to take on the mantle of leading industrialization, different national systems of innovation came to be recognised as viable. Particular countries retained particular strengths in certain sectors, even as new technological paradigms emerged, so that countries to some extent followed parallel paths towards long-term development rather than the crude convergence often posited in one-good models set at the macro level. This persistence at the sectoral level has been perhaps more consistent in sectors focused on technology production rather than technology use, for example Germany in chemicals – compare for instance the USA in information technology with the same country in motor vehicles, notwithstanding its resource advantages in the latter through cheap petroleum. This seems compatible with the findings of Archibugi & Michie (1997) on techno-globalism, establishing that this is strong in the exploitation of technologies but weak in the generation of technologies. Evidently catching-up and even overtaking countries find it harder to break into the science-based and information-intensive sectors of the Pavitt taxonomy (Pavitt, 2001) than the remainder. Although I am not aware that such contrasts have been analysed, this presumably in turn has to do with both the complexity of the sectors concerned and the patterns of dynamic capability that different sectors establish. The differences in learning modes implied in Lundvall’s position that learning-by-interacting is at the heart of national systems of innovation (Lundvall, 1992) would seem to deserve further attention by scholars. But how does this seeming lack of convergence across countries at the technological level relate to the governance modes previously discussed?

Evolutionary theory of governance

We now move into much more speculative territory, where questions rather than ‘answers’ come to predominate. We need to provide some kind of evolutionary theory of governance, at least to some extent paralleling that in technology, before we can reasonably proceed to examining their coevolution. But we do not have any even preliminary consensus about what an evolutionary theory of governance should look like. Somehow patterns of structure and control have to be placed on an evolutionary footing.

The starting points are however promising. To begin with, many scholars have presented arguments about the differences in national systems of governance. For example in the area of finance, Albert's *Capitalism against Capitalism* (1993) presents the notion that the world of finance can be divided into at least two sharply contrasting camps – the Anglo-Saxon and the Rhineland-Nippon. These differ less in their financial processes and products – they are all part of a highly globalised world of international finance – than in their structures and patterns of control, i.e. in their modes of governance. Similar arguments about national system differences can be presented for other systems in the economic world apart from technology. Since national modes of governance are likely to subsume technology into other functions, such as production, marketing and finance, the case for variety of governance experience at the national level seems plausible enough, even if there may be much disagreement about how to categorise any one particular nation state.

Secondly, I have already made the argument that national governance modes are likely to be characterised by complexity, in breadth at least. That is, throughout the industrial era, markets, corporate hierarchies, political hierarchies and networks have coexisted in virtually all countries of at least moderate size. The relative importance of each mode may have waxed and waned with the successive long waves, and may have varied from one country to the next at any point in time, but throughout all modes had to find the means to coexist with one another, whether through working together or working alongside each other.

In some other ways, however, things get more difficult in moving from technology to governance. One immediate issue is how to separate – or interconnect – ownership and management. 'Capitalism' as a mode of governance, denotes as already implied a system where the owners of capital – not its managers – exercise effective control. Instead, capitalist owners could be owning labour-managed enterprises or activities, for instance private universities or legal partnerships. Getting the interests of managers to coincide with those of the owners raises the issue of principal/agent problems. Indeed this is where Adam Smith raised his objections to managing large firms, where he thought the self-interest of managers would prevent any coherent strategy for the firm or organisation. He instanced above all the East India Company, the ultimate embodiment of British 18th-century mercantilism, as doomed to fail on these as well as other grounds. In this he was to be challenged by his 19th-century successor, John Stuart Mill (1848), who argued that owners could institute incentive mechanisms to ensure that managers would act in the owners' (principals') interest, and in any case their 'zeal' would promote collective rather than individual interest. But Mill had some self-interest of his own in arguing this, since it was the same East India Company that provided his own employment for many years.

It seems conceptually straightforward to distinguish Capitalism, the exercise of capital-power, from Socialism, where labour-power exercises control. As we know from historical experience, the reality is often less straightforward, since political hierarchies step in to provide de facto control where the unaided labour-power is seen to be inadequately effective. The case of the Former Soviet Union and subsequent Soviet empire is of course obvious. Here the centralised state owned and targeted, while management remained the responsibility of the individual enterprise, with a bias towards the giant enterprise. A conceptually interesting – if in practice abhorrent – alternative was National Socialism as in late 1930s Germany, where in theory ownership remained private while the state took over management. A more comfortable further alternative is the kind of 'market socialism' that emerged in some degree in Yugoslavia in the 1960s, where firms remained mostly small and were regulated through markets rather than through the state. This discussion of 'varieties of socialism',

superficial as it is, already shows up the potential complexity of the relationships between enterprises, markets, networks and the state.

The same goes *a fortiori* for any discussion of ‘varieties of capitalism’, on which there is a burgeoning literature as already briefly indicated at several points. Not only are there substantial differences among countries within particular functions, as suggested for finance, there are even more powerful differences between functions in respect of patterns of control, as implied in the supremacy of finance capital over industrial capital for 20th-century Britain. The Chandler depiction of contrasts between Britain’s personal capitalism, Germany’s collective capitalism and the US’s corporate capitalism – whether adequate or inaccurate in its own terms – is only part of this story.

It would be evidently desirable if we could apply something like the Dosi framework of paradigms, heuristics and trajectories to describe governance regimes as well as technological regimes. Until we get some taxonomy suited to categorising governance regimes, we are not likely to get far with sketching out the paradigms. However on the positive side, the economic governance and political governance literatures have made great strides towards categorising some of main components of a mode of governance. For example, we have the industrial organization literature on vertical and horizontal relations between firms and within firms, and again we have Chandler’s ‘visible hand’ work on different structures of firms (unitary, departmental, divisional, etc.). From the political governance literature we have different ways of categorising states, e.g. as being predatory, developmental, or intermediate (Evans, 1995), with strong implications for both structure and control. Less has been done on developing taxonomies for markets – though it is widely agreed that the market for labour, say, is very different from that for money or indeed goods – or for networks, though on the latter see for instance Hollingsworth & Boyer (1997) or Cooke & Morgan (1998).

To a degree these categorisations of the key elements of a mode of governance imply heuristics as well as paradigms. Simply put, the objective of a hierarchy – introduced to exercise control – would seem to be acquiring more and more control (Beniger, 1986). Even markets and networks, with their apparently more egalitarian connotations, can be thought of as at least redividing control – thus markets involve the loss of control over some items to obtain greater control over other items that these are exchanged for. And even markets, as the Pareto optimality argument shows, redivide ‘equally’ only to the extent that there is an equal initial endowment of resources. If the initial resource distribution is unequal, market forces will of their own accord simply reproduce that.

To have much explanatory power, we perhaps need to put these control-oriented heuristics – which of themselves are a kind of restatement of what governance is after all about – in a more teleological context. What is the goal of increasing, or for that matter reducing, control? Who or what is affected, and how? At this point I need to bring back Industrialism and the issue of technology.

The governments of nation states supported industry long before the First Industrial Revolution – for instance in medieval times either for sustaining employment and living standards or for overthrowing the economic power of rival nation states. Whether for national employment considerations or international competitiveness considerations, the support for industry was a means to an end, and those ends in turn were the means to propping up the power of the government in a situation where its authority was becoming less absolute and more subject to internal as well as external challenge. Only with the Industrial Revolution

proper did industry become to a greater extent an end in itself, and even there it represented as I have already pointed out a threat to incumbent agricultural interests as well as a response to emerging industrial interests. (We might note in passing that even today, when services represent about two-thirds of the employment and the output of a modern 'industrial' economy, there are still many who regard manufacturing as the basis of support for national levels of employment – indeed, a technological argument, at least, can be made out in favour of this apparently obsolete view). The reasons are, perhaps, both economic and technological. On the economic side, industry under the impetus of the industrial revolutions alone becomes powerful enough to support sustained growth, through generating sufficient economic surpluses to plough back into sustaining that growth. Secondly, and in conjunction, the new technological paradigms and their heuristics provide the directions of sustained expansion. I have previously argued that what distinguished industry and its technologies in the era of industrial revolutions from pre-modern industry was that now 'change became the norm' (von Tunzelmann, 1985). While there were undoubtedly technological advances, and often dramatic ones, in medieval times, like Freeman's reference to water power, they arose erratically and individually rather than as a 'self-sustaining' sequence.

Through the pursuit of the new and extraordinarily fruitful technological regimes, manufacturing industry thus found it possible to accumulate surpluses over time could be ploughed back into further investment embodying more technology in its machinery and equipment. With a market-based rather than network-based system, it was essential to be able to buy technology in such embodied form. Although the machinery industry spun off from the user industry, like textiles, and subsequently the machine tool industry spun off from the machinery industry, once they spun off their interlinkages in the UK became mostly market-mediated – the path of development in the technology dimension was unequivocally towards vertical disintegration. The combination of division of labour and markets yielded the benefits that Smith predicted. Smith had however also pointed out that capital embraced human as well as physical capital. The British system in this era was predicated on an absence of independent generation of human resources – under a governance system of personal capitalism and a production system driven by labour process under labour control (Elbaum & Lazonick, 1985), all the necessary accumulation of human capital could take place in-house through learning-by-using. While Smith and all successor classical economists called for the state to provide mass education, nothing was done to institute state-provided primary education for the multitude in the UK until after 1870, when the Second Industrial Revolution was already under way and fears of losing competitiveness to Germany were coming to be more frequently voiced (Jevons, 1865).

Germany, Sweden and most of the USA by this time had well-established and effective educational systems funded by local or national/federal governments. The Second Industrial Revolution further called for a concerted effort to develop publicly funded facilities at the level of higher education and frontier scientific research. But states had had an inconsistent alliance with industry or development generally over preceding centuries, and indeed after. Out of Smithian self-interest governments would be expected to accumulate surpluses to enrich themselves, and so indeed they usually did. Government surpluses could be expended on lavish gladiatorial combats in Ancient Rome or patronage of the arts in Renaissance Rome, but very much consumption oriented rather than investment oriented, and with little of it directed to the community at large rather than the privileged few. The typical surplus-accumulating state was thus of the predatory kind; the developmental state makes little impact until there are self-sustaining technological trajectories to point the way to the desired development. It is not difficult to see why, in the days before self-sustaining industrial

trajectories, political economists such as Adam Smith would have wanted to see the state wither away – but also to see the anti-developmental mercantilist companies wither away.

The simplest proposition is that societies wanting development have to direct their surpluses, from both public and private sectors, to developmental interests. If the private sector fails to do so, corporate failure will result, if the public sector does not, government failure will result. But there is no necessary reason why the heuristic of increasing control will lead to this outcome. As just hinted, the pressure of increased control at the level of governments, coupled with the self-interest principle, might be expected to strengthen predatory states, and of course that is what often happens in rapaciously rent-seeking governments of present and past times. Even in more developmentally minded governments, much of their surplus may well be directed to military activities, including military technology, with dubious effects on industrial development.

In such fairly familiar contexts, the negative heuristics of what not to do may be as significant as the positive ones – the forces, if any, countervailing the drive towards increasing control. An important aspect of these heuristics is the issue of centralisation vs. decentralisation. Increasing control is naturally best served by increasing centralisation, assuming you are the authority in question. That is unlikely to be best for development. The experience of state socialism in the Former Soviet Union showed the serious and possibly overwhelming drawbacks of extreme centralisation, partly as Hayek argued through the excessive demands placed on knowledge, stretching the bounds of rationality far beyond supportable limits. Similarly at the corporate level, the solutions to structure advanced by Chandler for the multi-product, multi-locational firm can be thought of as ways to institute decentralisation without abandoning some role for the central office.

Exactly how this decentralisation should be instituted, if indeed political forces allow it to be, is less obvious. The decentralisation of socialism as in the Former Yugoslavia and in small-scale experiments elsewhere barely got off the ground, despite substituting a supposedly impartial market for a partial (political) hierarchy. At the corporate level, as I have pointed out elsewhere, the Chandler solution of the multidivisional company (M-form) worked for the relatively stable technological conditions of the mid-20th century but was less able to cope with radical change. In relation to the phases of technological expansion, it may be asserted as a working hypothesis that greater decentralisation best suits the generation phase of technological revolutions, whereas greater centralisation – like in the M-form company – may be better during the subsequent consolidation and extended application phases.

Over the industrial revolutions, there would also seem to be natural affiliations. The labour-managed firm of the British Industrial Revolution – run by overseers and foremen – was no great handicap in an environment of small-medium firms with labour-oriented production processes. production was decentralised and mediated mainly through markets. As accumulations of capital became significant in the Second Industrial Revolution, considerations of sunk costs and asset specificity (to use transaction cost terminology) went with capital processes and capital-managed operations, hence centralisation albeit tempered by new organisational structures and electricity-based technologies. Finally in the Third Industrial Revolution, information and communication implied distributed processing, which came to replace the IBM view of the centralised computer; the growing significance of information processes logically accommodated the networked firm.

Superimposed on these were the requirements for creativity and application. Creativity is usually supposed to thrive best in a non-hierarchical environment, where the creators have the autonomy to pursue their own lines of thought wherever these take them. The application of those creations may, in contrast, benefit from centralisation and from hierarchical control, along Chandlerian lines. The different basic nature of the production processes and the knowledge processes thus generated different and somewhat contradictory heuristics for the evolution of governance over time. There was substantial mismatch in the transition phases, which corresponded with the technology creation phases and exacerbated the productivity slowdown consequences.

Coevolution

In a nutshell, the answer to the question ‘why coevolution?’ is that coevolution will not necessarily occur. Coevolution implies that the industrial evolution along the path of technology creation and application aligns in some fashion with the governance evolution, along the lines of surplus creation and application. However there is not necessary reason for these to coincide either in space or in time, and indeed most often they have not. At the same time, the circumstances and frequency of coincidence in the modern era are too common to suggest that we are dealing with random intersections.

We first need to say a little more about what ‘alignment’ signifies. In principle the issue is similar to the purpose of ‘régulation’ (a word which, as its sponsors point out, has no direct English translation) in the social systems of production approach, though there are differences of complexity and generality. Systems of the kind I am talking about comprise many elements – people or organisations. These individuals may hold a variety of views about their objectives and their interaction, many of which may be contradictory. The alignment issue aims to direct their multiple objectives towards a commonly accepted outcome, without necessarily forcing them to abandon their differences of viewpoint. The ‘network alignment’ concept which we are developing thus envisages disparate members of a network who nevertheless all benefit from their network-based interaction in ways – possibly different ways – that suit each of them. The régulation school has a similar viewpoint but mostly in a context of hierarchies.

Figure 1 illustrates a network alignment situation for the development of Taiwan’s IT industry (Kim & von Tunzelmann, 1997). The three governance poles of markets, firms and the state are arranged around and depicted as rectangles. Markets here refer mainly to foreign multinational companies, sourcing IT products and components from Taiwan. Firms correspond to the corporate hierarchies of our previous discussion, though were primarily constellations of small enterprises here. The state acts as the political hierarchy though there are significant local as well as national government activities. The three are interconnected by various types of networks into which they have varying inputs. These networks differ in geographical extent but also in intent. The global networks interface the foreign multinational demand with local suppliers. power rests more with the global players, but this is ameliorated in two ways. First, the government induces the return of overseas Chinese, e.g. from Californian high-tech companies or universities, who act as personal brokers between foreign and domestic. Second, in recent years the rather passive OEM relationship has evolved in some areas into what is called advanced OEM, or here ‘full-service OEM’, which plays a more active and self-driven role in, for example, supplying advanced technologies. Next, the state founded the Hsinchu science park in a region fairly near Taipei, and supported out of

public funds the main research institute (ITRI), which provided not only technologies but also training for local high-tech development. The nationally-based production networks of the third circle involved as a key element the interrelationships of large numbers of small, fleet-footed firms. The links to the locally-based science park and its institutes provided spillovers not only of technology but also of entrepreneurs, as those recruited into the science park were given strong incentives to split off and set up their own companies. Of particular interest in the Taiwanese case is that the arrangement was not as cosy as it perhaps sounds. The government – Kuomintang and thus mainland Chinese until recently – was deeply at odds with the business class, composed mainly of island Chinese. That did not stop mutual benefit from this network alignment.

The network alignment approach seeks to connect the two main kinds of elements that constitute the economic system, namely the resource flows and the (multiple) agents. Resource flows connect agents with one another, but the actions of agents can span across several types of resource flow. There is thus no one-to-one mapping between resources and agents, and the functions of agents are likely to overlap. The structure of the ‘networks of networks’ form would consist of a multi-layered tensor, in which demands and supplies are matched within each layer (e.g. flows of labour resources between households and firms as two kinds of agents) and between layers (e.g. matching these labour flows to flows of foreign direct investment between foreign and domestic firms). Dynamic changes over time, and path-dependencies, become a fourth dimension in the system.

As already implied, various mechanisms must exist to assist in the matching process, or otherwise growth would have been the exception rather than the rule. Part of the task is to identify the nature and role of those mechanisms. A probably incomplete list would include the following.

- 1) Institutions. The development of institutional arrangements, to which North (1990) has rightly drawn such attention, present one bridge between governance modes and industrial systems. The rise of legal systems pursuing justice but also protecting ownership and property is evidently crucial, as North states. In the sphere of technology creation, the development of intellectual property systems such as the patent system, aiming to balance the needs for creation against the public needs for diffusion and application, is apparent. Many other kinds of institutional arrangements also intrude, e.g. financial systems, educational systems.
- 2) Incentives. Evolutionary economic perhaps has more to learn from traditional economics about the importance of incentives. The details of particular governance systems may or may not provide the best encouragement for industrial expansion. Of course, if they do not, then such expansion becomes much more difficult. This may entail a delicate balancing act between competition and collaboration. A case in point has been the Korean system of government subsidies for industry, which came mainly in the form of cheap loans for the ‘chaebol’ (larger firms). This were so arranged that firms would continue to receive them only if they were successful in meeting government economic targets, principally for exports – if they failed, the subsidies went to other firms. Once the system fossilised around certain chaebols, however, cronyism rose and if anything the financial situation of those chaebols was worsened.
- 3) Knowledge bases. Both governance systems and technological systems evidently draw crucially upon existing and often idiosyncratic knowledge bases, which may or may not cross-relate. Mokyr (2001) has recently revisited the question of the role of knowledge, including scientific knowledge, in the British Industrial Revolution. he argues for

dividing knowledge into ‘what’/‘why’ knowledge (taxonomic/scientific knowledge or ‘epistemic’) and ‘how’ knowledge (technical knowledge). The former was widespread across countries of Europe in the mid-18th century, the latter was much more concentrated in Britain. Hence we might account for ‘why Britain was first’.

For all these mechanisms and no doubt others, ‘alignment’ still works in mysterious ways. Let me revert to the historical case of the British Industrial Revolution. That Industrial Revolution conventionally dated to the later 18th century was preceded by ‘revolutions’ in other related fields. Among the best-known are the Financial Revolution, conventionally dated to 1690 (the founding of the Bank of England), the Commercial Revolution (overseas trade and shipping, around 1651), the Agricultural Revolution (nowadays seen as originating in the mid 17th century), the Political Revolution (the triumph of property ownership, attributed to the revolution of 1688), and especially the Scientific Revolution (dated to the founding of the Royal Society in 1662). These all fall within a remarkably short span of year in the second half of the 17th century, and hence of course about a century before the Industrial Revolution proper. Historians have strangely ignored the synchrony in time of these events but pored over each of their links to the Industrial Revolution, mostly without success. There was little emerging in content (‘what’ and ‘why’) from the Scientific Revolution which had any perceptible impact on the early stages of the Industrial Revolution. Most indeed did not bear their own full fruit until later (see Figure 2). But ‘somehow’ (the word is Rostow’s) there must have been some connection. The issue remains entirely open.

Conclusions

The primary aim of the paper is to argue that historical experience poses a central problem in regard to explaining industrialization and development which has been little addressed in the evolutionary literature other than in some very specific ways. Yet that problem is inherently evolutionary. The problem concerns the matching between the evolution of technology, which has taken centre-stage in the evolutionary literature, and the evolution of governance, which has been largely left to others to trace and account for. Historians have tended to consider the two as of rival importance; more to the point, they have somewhat uncritically assumed an interdependence which more detailed historical examination suggests is unwarranted.

Theories of governance also turn out to be mostly of only limited use. Each of the main contenders helps to tell part, but only part, of the historical story. Thus economic theories of governance limit themselves to markets and hierarchies, occasionally networks, and in any case are predominantly static. Political economy theories mainly relate to states vs. markets. Political theories of governance place states and sectors at their focal point. The approach which comes closest to what I have in mind is the ‘social systems of innovation’ one, but even this needs to be generalised across historical patterns of change, and subjected to more general consideration. The standpoint of different types of failure in the bulk of the literature – market failure, corporate failure, government failure – itself fails to recognise their interdependencies. The evolution of governance is a dynamic compound of all of these, also calling on support from institutionalist and other theoretical frameworks.

The primary call of the paper is for two things – the development of an evolutionary theory of governance, and the explanation of the coevolution of governance and technology. Extending evolutionary theory to governance will call on its ability to account for variety as well as

temporal patterns, since all major modes of governance – markets, corporate hierarchies, political hierarchies and networks – have coexisted in the industrial era, though some have eclipsed others at various points of time. Moreover governance is inherently multi-dimensional – it is not just the mode of governance (‘what’) but also the agents (‘who’ – capital-owned or labour-owned, capital-managed or labour-managed) and the associated processes (‘how’ – labour processes, capital processes, information processes). The paper contends that the key issue is not just to isolate these strands but to explain how they align with one another. There is also the issue of multi-dimensionality at the functional level – technology is itself one of the functions that governance seeks to encompass, along with finance, production, marketing, etc.

Arguably, however, some of the same problems arise even within the evolution of technology. As Archibugi (1991) pointed out in his thesis, cataloguing technology involves considering ‘subject’ (what technology is created), ‘object’ (what it is applied to), and ‘agent’ (who does this – which firms or individuals). Each leads to a different classification for the schedule of technologies. Explaining the pattern of technological evolution requires cross-relating the three perspectives. This is in line with the present paper though not how evolutionary approaches generally tackle the question. It is also related to what can be suggested for an evolutionary approach to governance, to consider the subject (the ‘what’ of the mode), the object (here the ‘how’ of the process) and the agent (again the ‘who’).

More directly, if we consider evolutionary theories of technology as being about processes of search and selection, the search phase obviously corresponds to the creativity issues I have noted. Selection is most often assumed, even by evolutionary theorists, to take place in markets, but in reality occurs through all modes of governance. For example, the development of cellphones in recent decades involved selection variously by governments, corporations, networks and markets, roughly speaking in that temporal order. Hence pursuing the nature and evolution of governance as well as its coevolution may benefit the more traditional evolutionary work on technology.

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