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# Historical coevolution of governance and technology in the industrial revolutions

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**Abstract**

While the relationships between technological change and organisational change have been widely observed in specific cases, little has been done to generalise about such interrelationships over the longer term. The paper uses historical evidence to categorise the principal changes in governance (covering the control, structure and process of systems) in the industrial epoch, which are seen as the successive predominance of markets, (corporate) hierarchies and then networks. These correspond to the successive importance of labour processes, capital processes and information processes. There appears to be a link with the three 'industrial revolutions' that have arisen at century-long intervals since the later 18th century, though the causal interrelationships remain uncertain and by no means necessary. Network alignment is suggested as a means for bringing about the coevolution of governance and technology in development processes. A number of mechanisms for matching technological with organisational change are suggested by the governance literature, although no one theory of governance appears able to explain the observed historical phenomena.
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## 1. Introduction

While innovation studies as a field has changed radically in many ways in recent times, some key issues from the historical record still lie outside its purview. Among these, and the subject of this paper, is the historical coevolution of governance and technology. Two points should be made at the outset. First, I do not claim that this issue has been ignored in the innovation studies literature—the question of the links between technological change and organisational change, for instance, is a very standard one. Moreover scholars such as 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 changes in governance and changes in 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.

## 2. 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. A number of definitions have been offered, from which I have taken the simplest and broadest of which I am aware, which is that of Prakash and Hart (1999): governance is "organising collective action". Since this is very comprehensive, it may be more helpful to set out what should be included within the scope of 'governance', which are here taken to comprise issues of structure, control and process. These in turn can be defined in a multitude of ways, but 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, while 'process' (of which less will be said here) refers to the implementation of structure and control. The decisions themselves can of course cover every kind of activity in principle, but for obvious reasons are limited 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, 1991). Hierarchies need to be separated as between corporate hierarchies, i.e. large firms, and political hierarchies, i.e. states. The key battle in the literature is over which of these best serves the purposes of achieving development and prosperity. This battle will be shown to be

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, in speaking of market failure, of corporate failure, of government failure, and indeed of network failure.

## 3. Theories of governance

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

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 and turn out to be especially relevant to the evolution of decision-making process. Issues of power and the state are explicitly avoided in the static setting but unavoidable in a dynamic context.
2) 'Public choice' theories, as an extreme version of neoclassical economics, see the state as no more than a collection of profit-maximising 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 pushing firms and corporate hierarchies into the background. The usual debate concerns the relative claims of the state and the market as sponsors of development, and 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. They deal with the multiplicity of forms of control and how these interact, geared to specific contexts for focus. Typical examples are the balance between independence and interdependence of a government bureaucracy (Evans, 1995) or the division of control between local, national and supranational government in the EU. The approach 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 school in innovation studies 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). A related approach, also of French origin but not in the domain of economics, is that on 'conventions', which are seen as shared value systems in a number of different 'worlds' (industrial, civic, etc.). These can be oriented to different products (standardised vs. non-standardised, etc.) or different production processes or technological structures (Gallouj, 2002). The emphasis in the regulation approach instead lies on the 'tuning' between different worlds, typically kinds of hierarchies, and including factors of production (labour and capital) as well as corporate and political hierarchies. A typical example is emphasising how the 'Fordist' system of mass production used higher wages both to attract employees on the supply side and to fuel mass consumption on the demand side. 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 North (1990), 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 seen as 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 and Rowthorn, 1995). A deeper exploration is needed.

## 4. 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 much less than their due.

The orthodox way of envisaging this evolution depicts three eras of ideal types of corporate hierarchies. The first era, of 'personal capitalism' or 'proprietary capitalism', consisted overwhelmingly of small producer firms, launching the

industrial world. Decisions were made, or at least reconciled, through the exercise of Adam Smith's 'invisible hand', i.e. markets. The second era 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 Chandler (1977) called the 'visible hand', i.e. of management. The third era 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 and Sabel (1984) supposed this to be a return to small enterprises, often in lower-tech industries, networked in industrial districts. Others point to interactions between large firms and small firms, or among the large firms themselves. Others again go outside firms and stress links of business to universities, or to government. Depending on which one chooses one might come to different conclusions about dating this phase. These are lumped together here and termed 'network capitalism', coming about again about a century after the second era of corporate capitalism. For the moment, its key characteristic can be thought of as an era in which external non-market links among companies and to other organisations became as significant as internal links within each of them.

In other words, the successive predominance of markets, corporations and networks can be observed in the evolution of corporate governance under industrialisation. These eras of corporate governance types were marked by revolutionary discontinuities as each emerged ('revolutionary' here does not mean abrupt, but radical). Cutting across these temporal patterns of evolving governance were what some see as distinctive national patterns—what could be termed '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* (Chandler, 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 found much to oppose in Chandler's stereotyping of national systems of corporate governance, quite apart from the underlying whiff of American triumphalism (e.g. Cassis, 1997; von Tunzelmann, 1999). The supremacy of entrenched US corporations has by no means gone unchallenged. 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), which largely pioneered incorporation.

It needs to be underlined that, in terms of governance modes, all major structures existed in all leading industrial countries to significant degrees throughout the modern industrial epoch. In this sense, governance is 'complex'. 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 modes play some role, often they complemented one another, as with incorporation at the government level sponsoring incorporation at the private level in the US. 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.

## 5. 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, 1997a; Freeman and 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 epoch, 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 divert from the main topic, 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 espoused here 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, 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. 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.

There are two especially important theoretical bases of this view. One is the notion of 'innovative choice' developed by Amendola and Gaffard (1988) based on Hicks' neo-Austrian notions of the roundaboutness of capital, here applied to intangible (technological) capital, in which there is an early phase of 'constructing' the intangible capital (knowledge base) and a later one of 'utilising' it. The second lies in the recent more applied studies of 'general purpose technologies', in the volume edited by Helpman (1998), in which pervasive new technologies begin in a particular sector but eventually come to be applied across many.

Taking a 'three industrial revolution' rather than 'five Kondratiev wave' interpretation requires technological breakthroughs to be bundled together (see Table 1 below), even where their origins were very independent and not necessarily exactly coincident in time. The long-wave tradition does, however, help 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.

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-

Table 1
A chronology of industrial eras

| | First Industrial Revolution | Second Industrial Revolution | Third Industrial Revolution |
|---|---|---|---|
| Approximate dates | 1750–1815 | 1870–1914 | 1973– |
| Location | UK | USA, Germany | USA, East Asia |
| Technologies | Machinery | Chemicals | ICT, biotechnology |
| (motive) | Water, steam | Electricity, oil | (Nuclear, renewable) |
| (material) | Iron | Steel, plastics | Silicon, smart materials |
| Automation | of Transformation | of Transfer | of Control |
| Process type | Labour | Capital | Information |
| Size of firm | Small | Large | Mixed |
| Advantages | Specialisation | Internal Integration | External Integration |
| Organisation | Entrepreneurial | Multidivisional | Networked |
| Industry structure | Competitive | Oligopolistic | Mixed |
| Type of Capitalism | Personal | Managerial | Collaborative |
| Mode of Governance | Markets | Hierarchies | Networks |

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. 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 'product lifecycle' approach at the micro level, and North/South development models of the 'new trade theory' kind at the macro level. Again full assessment of why these perspectives are inconsistent with present findings would constitute a separate study, but briefly it may be asserted that differences in the unit of analysis are critical.

Going back to the 3-fold 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 the way to see it—as machine-assisted labour. It was only in the Second Industrial Revolution that the key characteristic became 'capital process' in Marx's terminology, 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 by 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.

A further implication of this view of historical sequence 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. For a historian there should be no puzzle about the 'productivity slowdown' in the Third Industrial Revolution of recent times, 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.

## 6. Causal links?: revolutions in governance and revolutions in technology compared

It may be concluded there have been three main eras in governance during the industrial epoch—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. An overview of a perhaps over-simplified classification is set out in Table 1.

We now, therefore, turn to the central issue of the potential linkages between these contemporaneous phenomena—the possible sources of their coevolution. Despite the apparent chronological connections, the issues of relating governance changes to technological changes 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. Attempts to trace precedence of one or the other in terms of time (which came first?) have not proved very fruitful, because isolated instances of precocious developments can easily be found on both sides.

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 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. 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 adamant about their respective views on priority. However, this was but the latest manifestation of a much longer debate (Cannadine, 1984)—in fact from the time the notion of an 'Industrial Revolution' was first popularised (Toynbee, 1884) two traditions have emerged, one pursuing what we would now call the revolution in governance, the other the more tangible revolution in technology. Implicitly rather than explicitly, historians have been arguing past one another, some talking about the rise of Capitalism, others

about the rise of Industrialism. To probe further into the extent and ways in which these overlapped and coevolved, I shall resort to evolutionary approaches: first to technology, which has become well established, then to governance, which has not.

## 7. Evolutionary theory of technology: key issues

Dosi (1982) has made a 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. The paradigm represents the broad field to which people resort in a particular era in order to solve pressing 'puzzles' in technical performance. Thus 'machinery' represented the dominant paradigm for manufacturing industry in the First Industrial Revolution (see Table 1) because when manufacturers encountered a technical problem in production, their first response was to seek a machine (mechanical technology) that would do the job better. If the broad area of technological application is then 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 have been the underlying physical constraints of time and space (von Tunzelmann, 1997a), exemplified by the role of miniaturisation in the evolution of information and communication technologies in the modern era, which gained economies not only in space but also in time, i.e. working much faster because of being so much smaller (Swann, 1986). Economies of speed were equally potent heuristics for both the First and the Second Industrial Revolutions (e.g. Chandler, 1977).

At the trajectory level, economies in time and space allow us to relate technological change to conditions of demand as well as 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.

There is, however, a potential trade-off between quantity and quality. In regard to the quality dimension, different countries have selected very different trajectories. Some countries choose a strategy of high product quality 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 trade-off (von Tunzelmann, 1997b); thus the US chose standardised products of moderate quality in order to advance mass production. Rapid growth can come about where process quality is interlinked 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 as noted in Table 1, but they take few away. Each new arena added not just itself, reading across the relevant rows of the table, but also (subsequently) some interdependencies with both old and new paradigms, 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. At the same time, the variety of ways in which such cross-linkages could be formed preserved national differences in technological paths at the sectoral level. Rather than any convergence towards a unique long-term development pattern, countries, therefore, pursued somewhat parallel courses in their technological structure, as seen for instance in comparing Germany with the USA in areas such as chemicals versus information technology. But how does this seeming lack of convergence across countries at the technological level relate to the governance modes previously discussed?

## 8. 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, the association between Industrialism and the rise of Capitalism has been pointed out above, hence suggesting capitalism as one paradigm for governance, that came to be pitted against another paradigm of Socialism. For present purposes, capitalism is taken to be a system in which structure and control are linked in the sense that effective power rests with those who possess the capital, while under socialism it is wielded by those who possess the labour-power. This immediately suggests a third possibility of control by those possessing the information/knowledge, as a prospect for any

emerging 'knowledge-based society' (e.g. Castells, 1996), but this is left as a matter of conjecture here.

Secondly, many scholars have presented arguments about more specific differences in national systems of governance. For example in the area of finance, Albert's *Capitalism against Capitalism* (Albert, 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 functions apart from technology, so 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. The Chandler categories of personal, corporate, collective and other forms of capitalism are one way of cutting into these national differences, as already indicated. These and other categorisations come to the surface in the burgeoning literature on 'varieties of capitalism' (e.g. Whitley, 1999).

Thirdly, it has been observed above that national governance modes are likely to be characterised by complexity. 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 stated, 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, an issue which can be traced back to Adam Smith's objections to managing large firms when self-interest might prevail.

While 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. But there are other 'varieties of socialism' (i.e. paradigms) just as there are varieties of capitalism; for instance the 'market socialism' in the former Yugoslavia of (supposedly) autonomous labour-managed

firms, or the 'national socialism' of Germany in the late 1930s, where in theory ownership remained private while the state took over management.

The heuristics of governance might perhaps best be approached by dividing the arena as previously into structure, control and process. The heuristics in structure have at different times appeared as centralisation or decentralisation. The prevailing pattern of course relates to the prevailing mode of governance, whether markets, hierarchies or networks. These in turn reflect differences in the type of advantage sought from the governance mode—of specialisation in market modes, of internal integration in hierarchical modes, and of external integration in network modes (see Table 1). 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 multidivisional company—may work better during the subsequent consolidation and extended application phases. The current network mode appears to be aiming at 'decentralised centralisation', as indicated for instance in the rise of companies aiming at 'systems integration' in their own neck of the woods, loosely connected with other systems integrators elsewhere. These relations may overlay and somewhat disrupt neat, pyramidal hierarchies. However, networks, in the very broad sense used here, once again come in many shapes and sizes, as greatly debated among sociologists (for illustrations in political economy, see for example Hollingsworth and Boyer, 1997). Political hierarchies have also sought various emphases upon or balances between centralisation and decentralisation at different times and in different places.

In regard to the heuristics of control, simply put, the objective of a hierarchy 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.

The heuristics of process would then have to do with negotiating or compelling structure and control. A very useful start in this direction is given by Richard Langlois' formulation of 'dynamic transaction costs' (Langlois, 1992), in which economic governance is not resolved by the rapid working out of an optimal balance between markets and hierarchies as in the static transaction cost case, but constantly renegotiated as the environment changes. Other possible approaches might be through dynamic versions of convention theory or institutional theory, but work to date has been rather rudimentary.

To have much explanatory power, we perhaps need to put these heuristics for structure, control and process—which of themselves are a kind of restatement of what governance is about—in a more teleological context. What is the goal of increasing, or for that matter reducing, control, or changing the structure? Who or what is affected, and how? At this point we can 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. 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 a threat to incumbent agricultural interests as well as a response to emerging industrial interests. 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—what distinguished industry and its technologies in the era of industrial revolutions from pre-modern industry was that now 'change became the norm'. While there were undoubtedly technological advances, and often dramatic ones, in medieval times, like 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 that 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 embodied in artifacts, particularly in the form of capital goods. Market-based systems, however, proved less successful in themselves in encouraging technology as embodied in people. While Smith and all successor classical economists called for the British 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). The Second Industrial Revolution called for a more concerted effort to develop publicly funded facilities at the level of higher education and frontier scientific research, a call that has been amplified in the Third Industrial Revolution.

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. 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 has often happened 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, perhaps crucial for national security but with dubious effects on industrial development.

Overlaying these patterns 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 which exacerbated the productivity slowdown consequences.

## 9. Coevolution

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 no 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 agents, each responsible for a transforming certain types of resource into certain types of output, e.g. firms (producing products), laboratories (producing technologies), universities (producing scientists), banks (producing finance), governments, etc. These agents 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 that is here taken to be economic advance, without necessarily forcing them to abandon their differences of viewpoint. The 'network alignment' approach 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.

Network alignment requires horizontal, vertical and sometimes diagonal complementarities in at least three dimensions, which can be briefly outlined for the case of firms. First are 'functional' networks, linking the functions of technology, production process, products (marketing) and finance, coordinated by management—in a corporate hierarchy, these functions will be internally linked. Second are 'resource' networks—supply chains but of various types, relevant to the full range of resource flows (capital, skilled labour, technology, etc.). The linkages here are usually externalised. Third are 'geographical' networks—the multiple levels in regional terms (local, national, global) at which activities are coordinated.

The development of Taiwan's IT industry illustrates effective network alignment (Kim and von Tunzelmann, 1997). The three governance poles of markets, firms and the state relate, respectively, mainly to foreign multinational companies (sourcing IT products and components from Taiwan), constellations of small enterprises, and the national political hierarchy (though with significant local government activities). The three have been 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, and power rests more with the global players, but this is ameliorated in two ways. First, the government induced the return of overseas Chinese, e.g. from Californian high-tech companies or universities, who acted as personal brokers between foreign and domestic. Second, in recent years the rather passive original equipment manufacturer (OEM) relationship with multinational companies has evolved in some areas into a more 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 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 thus 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. A structure taking the form of 'networks of networks' would perhaps 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) Power relations. A recent and still unfinished attempt to unveil historical patterns in the evolution of power during the industrial epoch has been made by the sociologist, Mann (1993). Mann considers that four main sources of 'social power' determine the structure of societies, namely ideological power, economic power, military power and political power. He shows how these became differently 'entwined' (i.e. aligned) as between the First and Second industrial Revolutions. However, for our purposes his approach is weakened by the neglect of corporate power and of processual change.
3) Incentives. Evolutionary economics 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). These 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.
4) 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'.

## 10. Conclusions

The primary aim of the paper is to argue that historical experience poses a central problem in regard to explaining industrialisation and development which has been little addressed in the evolutionary literature other than in some very specific ways. 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. 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.

The historical exegesis hints that, within the complex pattern of change suggested in Table 1, there are some key driving forces, notable new production processes on the technology side and new structures on the organisational side. The causal links between these appear to run in both directions, pushed on the one side by technological evolution (Industrialism) and on the other by the evolution of governance (Capitalism). How these were aligned is far from fully understood, though some matching agents (institutional change, power relations, economic incentives and knowledge bases) have been noted. Governance patterns were always complex in the sense of heterogeneity (breadth), while technological patterns have been becoming more so, and also more complex in depth (analytical difficulty).

Finally, in terms of patterns over time, 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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