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On the Social Evolution of Knowledge

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In *Understanding Knowledge as a Commons*, Hess and Ostrom (2007: 4) note that *commons* is a general term referring to a resource shared by a group of people. Traditionally, the word commons has been associated with physical resources such as grazing land or fisheries but more recently it has been applied in the context of the knowledge economy. Both knowledge resources and environmental resources are products of evolutionary processes but knowledge resources differ from natural resources in a number of important respects. While natural resources exhibit a high degree of subtractability – use by one reduces the amount available for others – the use of knowledge by one party does not diminish its availability for consumption by others. This non-rivalrous aspect of knowledge may lead to problems of supply since each potential knowledge producer secures only a small proportion of the total benefits to which his or her innovation may give rise. The standard solutions proposed to address this issue involve either government subsidies or the creation of intellectual property rights which allow the innovator to monopolise the benefits deriving from his or her creation for a limited period of time. But, as has long been recognised, property rights do not necessarily solve the problem of undersupply. They may be costly to enforce effectively and may create opportunities for rent seeking. In general, the increased supply is obtained at the cost of delayed diffusion. Moreover, as Frischmann (2012), has noted, when account is taken of the fact that knowledge is built cumulatively over time, and that present knowledge is an input into future knowledge, it is by no means certain that the long-term impact of intellectual property rights is an increase in knowledge output.[1] Hence, the need to identify new institutional/social frameworks to govern knowledge production.

[1] Concerns relating to the proliferation of intellectual property rights in biomedical research on both upstream and downstream innovation led Heller and Eisenberg to suggest a tragedy of an anti-commons leading to the underuse of scarce resources because too many owners can block each other (Heller and Eisenberg 1998). Subsequent research has indicated that this is less of a problem than originally thought especially with regard to upstream investment

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The terms 'knowledge economy' and 'knowledge commons' are relatively new and are motivated by the perception that the role of knowledge in the economy is increasingly important and that technologies such as the Internet are of their nature shared resources. While the shared and distributed features of the Internet have made it natural to think of it as a commons or at least a potential commons, Madison et al. (2009) emphasise that 'knowledge commons' refers not to properties of knowledge itself but to an institutional approach to governing its management or production. What makes something a commons is not inherent in the resource but depends on the relationship between the resource and the relevant user/producer community. If being a commons is not something inherent in a resource but rather built from 'intentional' human activity, it becomes important to understand the histories and narratives that underpin commons management of the resource in question. As Madison et al. (2009: 375) note, we need to ask questions such as: why a commons might be good thing in a particular context, whether perceptions have changed over time and what conflicts were embedded in changes of narrative and perception.

This chapter aims to examine the historical emergence of the main narratives relating to the broad categories of knowledge relevant to economic progress. In doing so, we need to remember that the relevant community depends on the particular context – sometimes it is humankind in general, sometimes a subset in the form of a nation, a particular demographic or specialist group. The narratives that today inform our understanding of knowledge emerged historically. It is therefore important to comprehend the circumstances which governed that emergence and of the changing relationship between knowledge generation, production and economic growth.

Our story begins at the end of sixteenth century with Francis Bacon's challenge to the belief in a classical golden age of knowledge inherited from the ancient world, and with his assertion that the progress of knowledge was continuing and cumulative and depended in large part on practical scientific experiment. It then examines the elaboration of this concept over the following two centuries and the beginnings of an understanding that knowledge evolution takes place within, and is dependent on, a wider social and institutional framework. The initiation of this approach is found particularly in the work of Mandeville and Ferguson in the eighteenth century. Both stressed that knowledge results from a wide collective process of learning derived to a large extent from everyday involvement in the ordinary business of life. This insight was soon lost as the classical political economists made capital the centrepiece of their theory of growth. The change in focus was originally due to Adam Smith who

(Eisenberg 2008). From the rather different perspective of profiting from innovation, Teece (2018) has pointed to the special problems associated with value capture in the case of innovators of enabling technologies and the consequent likelihood of private underinvestment in innovation in these technologies.

for methodological reasons singled out capital as the connecting principle binding together various factors contributing to growth (Thomson 1965; Smith 1980: II.12; IV.19). Although challenged, amongst others by Bentham, List and Rae, this catch-all concept of capital as the driving force of productive change dominated economics through most of the nineteenth and twentieth centuries. Meanwhile, the concept of communally acquired knowledge was either classed as an externality or transferred, with Edmund Burke and the German historical school, into the study of civil institutions where it became associated with preservation of tradition rather than progressive change. Only with the development of the knowledge economy in the later decades of the twentieth century has the focus on knowledge as the driver of progress returned to centre stage.

2.1 KNOWLEDGE: THE PRODUCT OF COMMUNAL EFFORT OVER TIME

Francis Bacon (1561–1626) is widely regarded as the initiator of the modern approach to knowledge with its focus on understanding and shaping natural processes and its vision of knowledge as the product of a communal effort rather than individual effort (Gaukroger 2001). For Bacon, the proper aim of science was the endowment of human life with new inventions and riches. This, however, did not mean that all scientific effort had to be immediately useful or profitable. As Bacon noted, the expectation of future progress required experiments that led to the discovery of causes and axioms that were enlightening as opposed to immediately profitable (Bacon 1902: 80). Bacon was of the view that excessive reverence for the thought of antiquity could hold back progress in the sciences and he challenged the then popular view of a golden age of Greece and Rome and a subsequent degeneration of mankind. Bacon argued that the use of the word antiquity with respect to the Greek and Roman world was misleading. Being earlier in time, the world was younger then and would therefore be expected to have a lower stock of knowledge. Bacon concluded, 'we have reason to expect much greater things of our own age ... than from antiquity, since the world has grown older, and its stock has been increased and accumulated with an infinite number of experiments and observations. Truth is rightly named the daughter of time, not authority' (Bacon 1902: 61–62). While Bacon emphasised that people in his own age had the potential to know more, he did not envisage any simple accumulation of knowledge. Obstacles in the form of idols and false notions needed to be guarded against or removed. New additions to knowledge required the use of appropriate methods (Bacon 1902: 8).

Bacon placed considerable emphasis on the importance of the mechanical arts and discoveries. The invention of printing, gunpowder and the compass had given rise to far-reaching changes in the state of the whole world: first in literature, then in warfare, and lastly in navigation. However, the importance of the mechanical arts for

Bacon lay not just in their impact but in the model they offered for the organisation of scientific inquiry in which the key to progress was collaboration (Eamon 1996).

> In arts mechanical the first deviser comes shortest, and time addeth and perfecteth; but in sciences the first author goes furthest, and time lesseth and corrupteth. So we see artillery, sailing, printing and the like, were grossly managed at first, and by time accommodated and refined; but contrariwise the philosophies and sciences of Aristotle, Plato, Democritus . . ., of most vigor at first, and by time degenerate and imbased; where of the reason is no other, but that in the former many wits and industries have contributed in one; and in the latter many wits and industries have been spent about the wit of some one, whom many times they have depraved rather than illustrated.
>
> (cited in Eamon 1996: 323)

Bacon's distinction between the potential for progress in the mechanical arts as opposed to philosophy was original to him. However, the view that progress in knowledge and invention was the product of communal effort over time was not entirely new. Hayek (1967) cited Cicero to the effect that Roman law was founded on the genius not of one man but of many and not in one generation but in a long period of several centuries and many ages of men. In the early eighteenth century, the physicians Georgio Baglivi and Bernard Mandeville both cited Galen as the original authority for the communal point of view (Prendergast 2014: 90–91). Probably the most influential medical researcher of antiquity, Galen sought a mid-way between pure rationalist and pure empiricist approaches to medicine and based his writings on experiments and dissection as well as theory. These became the mainstay of medical training for well over a thousand years, being superseded only in the mid-sixteenth century. Having defined history as 'an account of what one has perceived oneself or an account compiled from books of those things on which all who have written about the matter agree', Galen argued that the empiricist has to make use of history 'because of the vastness of the art, since one man's life will not suffice to find out everything' (Galen 1985: 33–34).

As Bury (1960: 78–97) notes, the challenge to the prevalent theory of degeneration which began in the early seventeenth century led, in France and England, to a century-long literary war over the comparative merits of the ancients and moderns.[2] It is no accident that the controversy arose at a time when scientific effort was accelerating and a millennium and a half of virtual stagnation was coming to an end. Amongst those who argued that contemporary learning had surpassed that of

[2] Fontenelle's *Digression sur les anciens et les modernes* in 1688 and a work along similar lines by Perrault provoked a response from Sir William Temple in the form of his *Essays on Ancient and Modern Learning and on Poetry* in 1690. Temple's essay focused English attention on the controversy and may have inspired Jonathan Swift's satirical Battle of the Books. Much of this wider literature debated the relative merits of the ancients and moderns and rehearsed Bacon's critique of pure rationalism and pure empiricism.

the ancients were the French polymath Blaise Pascal (1623–1662) and the science populariser Bernard le Bovier de Fontenelle (1657–1757). Pascal's position is set out in the Preface to his *Treatise on Vacuum* first published in 1651. In the said Preface, Pascal explained why knowledge was cumulative in the sciences that are subject to experiment and reasoning and, consequently, why the knowledge of the present generation in these subjects was greater than that of the ancients. Men differed from the animals in that they were capable of accumulating knowledge (Pascal 1910: 448).

> [Man] is ignorant at the earliest age of his life; but he is instructed unceasingly in his progress; for he derives advantage, not only from his own experience, but also from that of his predecessors; . . . And as he preserves this knowledge, he can also add to it easily; . . . not only does each man advance from day to day in the sciences, but all mankind together make continual progress in proportion as the world grows older, since the same thing happens in the succession of men as in the different ages of single individuals. So that the whole succession of men, during the course of many ages, should be considered as a single man who subsists forever and learns continually.
>
> (Pascal 1910: 449)

The metaphor employed by Bacon and Pascal in referring to their own time as the old age of the world had the drawback that it appeared to exclude the idea of indefinite progress of knowledge (Bury 1960: 109). Rejecting the metaphor, Fontenelle argued that mankind would have no old age because the sound views of scientific men in successive generations would continually add to what was already known.[3] Scientific progress would therefore go on indefinitely. Progress in the sciences was the result of chance but had its own order and rule. Each addition to knowledge happened only when earlier discoveries had laid the foundations for it (Devaille 1910: 215–217; Bury 1960: 110–113). In other words, human knowledge develops in a structured manner with the later possibilities being determined by the earlier achievements. This broad position on the progress of knowledge appears to have become the new orthodoxy. As shown below, in one form or another, a series of writers including Mandeville, Ferguson, Turgot, Condorcet, Babbage and Marx saw knowledge as an ever-growing product of the joint labour of several ages.

Both Mandeville and Ferguson are discussed in later sections of this chapter, so reference to them here will be brief. Mandeville's commitment to a cumulative and collective view of knowledge is evident in a number of his works but especially in the second volume of his *Fable of the Bees*. There, he refers to many useful arts and

[3] While Fontenelle's point is important, it is worth noting that much of Bacon's effort was directed towards removing the obstacles to progress in the sciences. He lamented the fact that men were satisfied by the small amount that had been achieved to date (Bacon 1902, I: A88). He also argued that one of the greatest obstacles to the advancement of the sciences was a lack of hope or the despair of success which, in turn, he attributed to men's perception of the shortness of individual life and the obscurity of nature (Bacon 1902, I: A102).

sciences being the result 'human sagacity in general, and the joint labour of many ages, in which men have always employed themselves in studying and contriving ways and means to soothe their various appetites, and make the best of their infirmities' (Mandeville 1924, II: 128). Likewise, in his *Essay on the History of Civil Society*, Adam Ferguson (1723–1816) wrote: 'men continue their works in progression through many ages together: They build on foundations laid by their ancestors; and in a succession of years, tend to a perfection in the application of their faculties, to which the aid of long experience is required, and to which many generations must have combined their endeavours (Ferguson 1782: 7).

The young Turgot (1727–1781), in his *Philosophical Review of the Successive Advances of the Human Mind*, wrote that 'all ages are successively bound up with one another by a succession of causes and effects which link the present state of the world with all those that have preceded it. The arbitrary signs of speech and writing, by providing men with the means of securing the possession of their ideas and communicating them to others, have made of all the individual stores of knowledge a common treasure house which one generation transmits to another, an inheritance which is always being enlarged by the discoveries of each age' (Turgot 1913, I: 215; Meek 1973: 41). Likewise, in his *Plan of the Discourses on Universal History*, Turgot referred to man transmitting his acquired ideas to his successors 'as a heritage which is always being augmented'. He continued: 'A continual combination of this progress with the passions, and with the events they have caused, constitutes the history of the human race, in which each man is no more than one part of an immense whole which has, like him its infancy and its advancement' (Turgot 1808: 212; Meek 1973: 63).

Written in 1793 while he was imprisoned by the Robespierre faction of French revolutionaries, Condorcet's (1743–1794) *Sketch for a Historical Picture of the Progress of the Human Mind* proposed that humankind progresses continuously towards perfection. Progress would continue in the future due to the destruction of inequality between different nations; the progress of equality in one and the same nation; and lastly, the real improvement of man (Condorcet 1796: 251). Like his mentor, Turgot, Condorcet believed that freedom of commerce would lead to greater equality within countries whereas his expectation of greater equality between countries was due to his belief that once development began in poor countries, it would progress rapidly because they could quickly learn things that had taken Europeans a long time to discover (Condorcet 1796: 254–259). As far as the amelioration of the human race is concerned, Condorcet thought that new discoveries in the sciences and the arts[4] would continue to be made, and, that as a consequence, there would be improvements in the means of individual and general prosperity. As new discoveries are made, they are gradually simplified and integrated with existing

[4] Condorcet believed that the view that progress in the arts was necessarily limited was no more than a prejudice (Condorcet 1796: 282).

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knowledge so that they can be grasped by those of ordinary capacity. Hence, the progress of the sciences allowed progress of the art of instruction, which, in turn, accelerated the progress of the sciences. As a result of better organisation of the knowledge that had been achieved, in every generation, 'what may be acquired in a given space of time, by the same strength of intellect and the same degree of attention, will necessarily increase' (Condorcet 1796: 285). Condorcet was also of the view that there would be a real improvement in human beings themselves as a result of better nutrition, housing, sanitation, regular exercise and medical practice (Condorcet 1796: 289–290).

2.2 THE SUBSUMPTION OF KNOWLEDGE WITHIN THE CONCEPT OF CAPITAL

It is evident that, by the late eighteenth century, authors such as Condorcet connected the accumulation of knowledge to wider processes of social change. This perspective was reinforced by the emergence in Scotland and in France of a stages view of history with each stage characterised by a different mode of subsistence and corresponding legal and social institutions (Pascal 1938; Meek 1976; Skinner 1982). Such a materialist and historical perspective implies recognition of the importance of institutions and there is no doubt that Smith, as a leading member of the Scottish branch of this school, was very much pre-occupied with establishing the institutional conditions under which the market mechanism would operate effectively (Rosenberg 1960). However, as Rosenberg has noted, later generations stripped the institutional aspect from Smith's presentation of the role of the price mechanism in resource allocation. Likewise, the relationship which Smith had postulated between capital and growth underwent important changes. Whereas in his discussion of growth issues, Smith used the concept of capital as a connecting principle subsuming other factors contributing to development, in the hands of his successors, capital accumulation came to be seen as the sole driver of development. As a result, the role of knowledge disappeared from view (Prendergast 2010). Although a number of authors criticized Smith and his followers for neglecting the accumulation of knowledge as an autonomous motor of economic growth, their critiques had limited influence and there was no systematic revival of knowledge-based approaches to economic growth until the twentieth century. Authors such as Hodgskin (1825) suggested an ideological motive for the focus on capital. Hodgskin argued that knowledge rather than capital was the source of increased productivity and that consequently capital had no right to appropriate the entire surplus.[5]

[5] Before many of our most useful machines and instruments could be invented, a vast deal of knowledge gathered in the progress of the world by many generations was necessary. At present also a great number of persons possessed of different kinds of knowledge and skill must combine and cooperate, although they have never entered into any express contract for this purpose, before many of our most powerful machines can be completed and

Arguments relating to the importance of the independent role of knowledge accumulation came from other quarters as well. Throughout his career, Charles Babbage consistently maintained that the arts and manufactures of a country were intimately connected with the progress of the 'severer sciences' (Babbage 1835: 379). In *The Exhibition of 1851*, Babbage noted that, in fulfilling their exiting wants and necessities, each generation availed of the knowledge bequeathed to them by their predecessors. They also purified the knowledge which it had inherited and added to it for the benefit of their children. Remember, Babbage argued

> that accumulated knowledge, like accumulated capital, increases at compound interest: but it differs from the accumulation of capital in this; that the increase of knowledge produces a more rapid rate of progress, whilst the accumulation of capital leads to a lower rate of interest. Capital thus checks its own accumulation: knowledge accelerates its own advance. Each generation, therefore, to deserve comparison with its predecessor, is bound to add much more largely to the common stock than that which it immediately succeeds.
>
> (Babbage 1968: 210–211)

Like Smith, Marx is mainly focused on the role of capital but his conception of capital encompassed social relations of production as well as fixed capital in the form of machines, buildings and so forth. In the early draft of *Capital* commonly known as *Grundrisse*, he was explicit that the full development of capital took place only when the machine as the technological application of science dominated the production process. Whereas Hodgskin emphasised that the knowledge which appeared to belong to capital really resided in the engineers and workmen who contributed to the creation of machinery, Marx appears to accept that the general productive forces of the social mind are absorbed into capital. As he put it:

> before they can be used. The labour of the draughtsman is as necessary to construct a ship as the labour of the man who fastens her planks together. The labour of the engineer, who 'in his mind's eye' sees the effect of every contrivance, and who adapts the parts of a complicated machine to each other, is as necessary to the completion of that machine as the man who casts or fits any part of it, without being sensible of the purpose for which the whole is to serve. In like manner the labour and the knowledge of many different persons must be combined before almost any product intended for consumption can be brought to market. The knowledge and skill of the master manufacturer, or of the man who plans and arranges a productive operation, who must know the state of the markets and the qualities of different materials, and who has some tact in buying and selling, are just as necessary for the complete success of any complicated operation as the skill of the workmen whose hands actually alter the shape and fashion of these materials. Far be it, therefore, from the manual labourer, while he claims the reward due to his own productive powers, to deny its appropriate reward to any other species of labour, whether it be of the head or the hands. The labour and skill of the contriver, or of the man who arranges and adapts a whole, are as necessary as the labour and skill of him who executes only a part, and they must be paid accordingly.
>
> (Hodgskin 1825)

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> The accumulation of knowledge and of skill, of the general productive forces of the social mind, is thus absorbed into capital, as opposed to labour, and hence appears as a property of capital, more precisely, of fixed capital, to the extent that it enters into the production process as means of production in the strict sense.
>
> (Marx 1987: 84)[6]

Later in the same work, he argued that:

> The development of fixed capital shows the degree to which society's general science, KNOWLEDGE, has become an *immediate productive force*, and hence the degree to which the conditions of the social life process itself have been brought under the control of the GENERAL INTELLECT and remoulded according to it. It shows the degree to which the social productive forces are produced not merely in the form of knowledge but as immediate organs of social praxis, of the actual life process.
>
> (Marx 1987: 92)

Marx is here acknowledging not only that knowledge is a productive force but also that knowledge is bound up and cannot be separated from society's structures and practices. As we shall see this view predated Marx and was to be found already in the work of authors such as Mandeville and Hume.

2.3 DIFFERENT VIEWS OF KNOWLEDGE

2.3.1 *Knowledge Is Not Separate from Artefacts, Practices, Laws and Institutions*

When authors such as Pascal and Fontenelle or even Turgot and Condorcet wrote about knowledge, they primarily had in mind formal scientific knowledge and knowledge of the arts. A very different way of viewing knowledge emerged in the writings of the Dutch born physician Bernard Mandeville (1670–1733). Mandeville agreed with his predecessors that knowledge is the product of communal effort taking place over long periods of time but the knowledge he has in mind is not necessarily embodied in symbols but could instead be embodied not only in artefacts but also in the practices of human beings as they go about the ordinary business of life. Particularly in volume II of his *Fable of the Bees*, Mandeville spelt out the means by which the joint labour of men of ordinary capacity led to progress in many useful arts and sciences.

[6] The Anglo Irish 'utopian' socialist William Thompson had earlier noted that 'knowledge was capable of being detached from labour and opposed to it. He saw this separation as something that accompanied progress. However, he was optimistic that the separation would be overcome in the co-operative society of the future (Thompson 1824: 274–275).

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> To men who never turn'd their thoughts that way, it certainly is almost inconceivable to what prodigious height, from next to nothing, some arts may be and have been raised by human industry and application, by the uninterrupted labour and joint experience of many ages, though none but men of ordinary capacity should ever be employed in them.
>
> (Mandeville 1924, II: 141–142)

Mandeville's particular example was a ship, specifically 'a first–rate man of war', which he regarded 'as vastly superior to any other moveable body of human invention'. He argued that, provided they had access to proper materials, that there were many 'sets of hands' in the nation that could produce such a ship in less than six months. The division of labour was key to this. The task would not be possible 'if it was not divided and sub-divided into a great variety of different labours; and it is certain that none of the labours require any other, than working men of ordinary capacities' (Mandeville 1924, II:142).

Mandeville emphasised that the progress that had been made in shipbuilding was not the product of genius or deep penetration but instead was due to the cumulative experience of many generations. The Chevalier Reneau had written a book in which he showed the mechanism of sailing and accounted mathematically for everything that belonged to the working and steering of a ship. Mandeville allowed that Monsieur Reneau's reasoning was correct but he insisted that those who first invented ships and who afterwards improved them were ignorant of those reasons. He continued:

> They are seldom the same sort of people, those that invent arts and improvements in them, and those that enquire into the reason of things . . . none succeed oftener in the first, than active stirring and laborious men, such as will put their hand to the plough, try experiments and give all their attention to what they are about.
>
> (Mandeville 1924: 144)

At one level, Mandeville is simply saying that the division of labour – a term which he was the first to use – plays a vital role in allowing the production of complicated objects and also in facilitating experiments and innovation. When people specialize, they not only become useful to one another 'but the callings and employments themselves will in the same number of years receive much greater improvements, than if all had been promiscuously followed' by each person (Mandeville 1924, II: 284). One might also note that a corollary of the division of labour is that knowledge itself is divided up. That gives rise to some advantages in that it facilitates the transmission of knowledge between generations through learning by doing, by means of apprenticeships, and by forms of specialist education (Mandeville 1924, I: 58–61). It also gives rise to the need for co-ordination – 'how to get services performed by others when we have occasion for them, is the grand and almost constant solicitude in life of every individual person' (Mandeville 1924, II: 349). Note

also that the references to Reneau's work suggest that scientific understanding of what has been created comes at the end rather than the beginning of creative activity. The full importance of this may be better understood, if we take account of the fact that what Mandeville wrote about ships applied not just to artefacts but to the laws and practices of human society as the following remarks relating to the regulations governing a large city make clear.

> Remember what . . . I told you concerning the arts of shipbuilding and politeness. The wisdom I speak of, is not the offspring of a fine understanding, or intense thinking, but of a sound and deliberate judgement, acquired from a long experience in business, and a multiplicity of observations . . .. It is common now to have clocks, that are made to play several tunes with great exactness: The study and labour, as well as trouble of disappointments, which, in doing and undoing, such a contrivance must necessarily have cost from beginning to end, are not to be thought of without astonishment: There is something analogous to this in the government of a flourishing city, that has lasted uninterrupted for several ages: There is no part of the wholesome regulations belonging to it, even the most trifling and minute, about which great pains and consideration have not been employed, as well as length of time; and if you look into the history and antiquity of any such city, you will find that the changes, repeals, additions and amendments, that have been made in and to the laws and ordinances by which it is ruled, are in number prodigious.
>
> (Mandeville 1924,II: 322–323)

2.3.2 *Knowledge as Problem-Solving Activity*

Mandeville believed in the primacy of practical over theoretical knowledge. This seems to have been in part a reflection of his view that practical knowledge was more comprehensive. In *A Treatise of the Hypochondriak and Hysterick Diseases*, Mandeville argued that the proper teaching of anatomy required more than knowledge of every part of the inside of the body. In addition, the student of anatomy should be 'expert at dissecting . . . He ought to know . . . the names of every muscle in the body and how to go to them readily and separate them from those they are annexed to, without mangling or injuring the adjacent parts' (Mandeville 1730: 196–197). Likewise, in volume II of *Fable of the Bees*, Mandeville attempted a distinction between different kinds of knowing which has something in common with modern distinctions between information and knowledge. There was, he argued, a great difference between knowledge in the sense of information received and stored and knowledge in the sense of ability to retrieve information and use it for our purposes (Mandeville 1924, II: 171). There were, Mandeville continued, 'Men of prodigious reading that have likewise great memories, who judge ill, and seldom say anything *a propos*'. 'Knowledge must have lain in their Heads, as Furniture at an Upholder's; and the Treasure of the Brain was a Burden to them, instead of an Ornament!' (Mandeville 1924: 171–172).

While those with book knowledge did not always have the ability to use it, Mandeville also pointed out that not all knowledge was expressible in words.[7] In the *Treatise of the Hypochondriak and Hysterick Diseases*, he noted that:

> A curious observer learns in time to distinguish, between things that very nearly resemble one another, have the same name, and seem to those who are less acquainted with them not to differ at all .... A man may know a thing perfectly well, and at the same time not be able to tell you, why, or how he comes to know it.
>
> (Mandeville 1730: 61)

As a further illustration of this point, Mandeville gave the example of his conviction that a certain painting was an original by Van Dyke. Although he was convinced that this was the case, it would be impossible for him to explain why it was so especially to somebody who had no skill in painting (Mandeville 1730: 62).

Consideration of the view that true knowledge related to the ability to act rather than book learning is also to be found in Adam Ferguson's *Essay on the History of Civil Society*, Ferguson (1723–1816) drew parallels between the activities of those engaged in scientific endeavours and those engaged in business. Both sought to 'collect a multiplicity of particulars under general heads, and to refer a variety of operations to their common principle' (Ferguson 1782: 43). They measured their own abilities by their capacity to identify what is important in every subject, and the facility with which they extricate themselves on every trying occasion. Ferguson emphasised that it was these, and not the extent of book learning which were 'the proper test of capacity and force'.

> The parade of words and general reasonings, which sometimes carry an appearance of so much learning and knowledge, are of little avail in the conduct of life. The talents from which they proceed, terminate in mere ostentation, and are seldom connected with that superior discernment which the active apply in times of perplexity; much less with that intrepidity and force of mind which are required in passing through difficult scenes.
>
> (Ferguson 1782: 45)

Men, Ferguson continued, should be estimated based not on what they know but what they were able to perform 'from their skill in adapting materials to the several purposes of life; from their vigour and conduct in pursuing the objects of policy, and in finding the expedients of war and national defence. Even in literature, they are to be estimated from the works of their genius, not from the extent of their knowledge' (Ferguson 1782: 48).

[7] Mandeville was amongst the first to devise an evolutionary theory of language. He believed that people would 'make themselves intelligible to each other by signs and gestures, before they would attempt it by sounds: But when they lived together for many years, it is very probable, that for the things they were most conversant with they would find out sounds, to stir up in each other the idea's of such things when they were out of sight' (Mandeville 1924, II: 288).

2.4 THE OWL OF MINERVA?

Earlier, it was noted that Mandeville's references to Reneau's work suggest that a full scientific understanding of what has been created comes at the end rather than the beginning of creative activity. Ferguson made a connected claim, namely that the forms of society 'arise, long before the date of philosophy, from the instincts, not from the speculations of men'. As he put it in the passage made famous by F. A. Hayek:

> Every step and every movement of the multitude, even in what are termed enlightened ages, are made with equal blindness to the future; and nations stumble upon establishments, which are indeed the result of human action, but not the execution of any human design.
>
> (Ferguson 1782: 205)

In a later part of the work, Ferguson explained that the 'establishments of men, like those of every animal, are suggested by nature, and are the result of instinct, directed by the variety of situations in which mankind are placed'. They arose from 'successive improvements that were made, without any sense of their general effect' and which cannot be fully comprehended even when the whole is carried into effect (Ferguson 1782: 304). Ferguson continued:

> Who could anticipate, or even enumerate, the separate occupations and professions by which the members of any commercial state are distinguished; the variety of devices which are practised in separate cells, and which the artist, attentive to his own affair, has invented, to abridge or to facilitate his separate task? In coming to this mighty end, every generation, compared to its predecessors, may have appeared to be ingenious; compared to its followers, may have appeared to be dull: And human ingenuity, whatever heights it may have gained in a succession of ages, continues to move with an equal pace, and to creep in making the last, as well as the first, step of commercial or civil improvement.

It is clear that, as with Mandeville before him, Ferguson was of the view that people act without awareness of the full consequences of their actions with the result that they may produce effects that they did not anticipate. Consequences may be unforeseen due to bounded rationality which, in turn, may be linked to complexity, on the one hand, and specialization, on the other hand. This, however, is not the whole story because, as we have seen, both Mandeville and Ferguson envisage a situation where innovation is taking place and each generation progresses beyond what was achieved by its predecessor. Since novelty of its nature has to be actualised before it can be analysed, an understanding of what has been created comes after rather than before the event. This is not to say that knowledge is unimportant – existing knowledge in whatever form is an input into the creation of the new. But as Hegel wrote in the introduction to *Philosophy of Right*, 'Philosophy, as the thought of the world, does not appear until reality has completed its formative process, and

made itself ready' (Hegel 2001: 20). Note, however, Ferguson's qualification that the establishments of men 'cannot be fully comprehended even when the whole is carried into effect'. In other words, human beings cannot even fully understand what they have already created.

2.5 CONTINUITY, REVOLUTION AND THE DIFFICULTY OF PREDICTION

Ferguson's contemporary, Edmund Burke (1723–1792) was also of the view that human beings were unlikely to fully understand the nature of the institutions they had constructed. He particularly emphasised that policy should be based on 'actual circumstances' rather than 'mere abstract principles' (Burke 1981: 193–194). He put this most colourfully and controversially in *Reflections on the Revolution in France* where he wrote of being unable to give praise or blame to anything relating to human actions or concerns 'on a simple view of the object, as it stands stripped of every relation, in all the nakedness and solitude of metaphysical abstraction' (Burke 1989: 58). He insisted that the science of constructing or reforming a commonwealth was an experimental science requiring long experience 'because the real effects of moral causes were not always immediate' (Burke 1989: 111–112). A policy that produced unfavourable effects in the short term might have good long-term consequences and vice versa. Since even a lifetime of experience might not be sufficient to appreciate the remote consequences of actions 'it is with infinite caution that any man ought to venture upon pulling down an edifice which has answered in any tolerable degree for ages the common purposes of society, or on building it up again, without having models and patterns of approved utility before his eyes' (Burke 1989).

Society was a contract but not an ordinary contract for goods which could be dissolved by the fancy of the parties. 'It is a partnership in all science; ... in all art; ... in every virtue, and in all perfection. As the ends of such a partnership cannot be obtained in many generations, it becomes a partnership not only between those who are living, but between those who are living, those who are dead, and those who are to be born'.[8] As such, the present generation were not at liberty 'to dissolve it into an unsocial, uncivil, unconnected chaos of elementary principles' based on speculations of contingent improvement. All of this implied that change should be approached with considerable circumspection because the results of change 'cannot be certainly known beforehand' (Burke 1989: 121). Despite all these strictures about the dangers of change, Burke was very much aware that change was important. He, himself, was a tireless social reformer and he insisted that a state without the means of some change is without the means of its conservation.

[8] The difference between Burke's position and that of the American founding fathers is suggested by Thomas Jefferson's letter to James Madison of 6 September 1789 in which he argued that one generation of men did not have the right to bind another.

Burke's *Reflections* was translated into German and was influential amongst adherents of Romanticism and the German Historical School of Law. The school rejected reason-based law and recognised traditional law as the established law. Its most important member was Friedrich Carl von Savigny (1779–1861). Against the philosophical school of natural rights, Savigny argued that true cognition of the human condition could only be established by historical means (Klenner 1989). No era gives rise to a new world arbitrarily. Everything new was derived from the entire past of a nation, and consequently was historically determined. Law emerged and developed not by legislative arbitrariness, but first by usage and popular belief and later by jurisprudence (Klenner 1989).

The main challenge to the historical school of German law came from Georg Friedrich Wilhelm Hegel who regarded the school as an apologia for the existing state of law. Hegel argued that that the law could not be based on mere habit. Everything needed to justify its existence before the tribunal of reason (Klenner 1989). In a criticism of the German historical school of law published in 1842, Karl Marx accused the school of making history self-justifying and of legitimizing the baseness of today by the baseness of yesterday (Kelley 1978). He pointedly criticised its position on knowledge accusing its adherents of supposing 'that because we cannot know what is *true*, we consequently allow the *untrue*, if it *exists* at all, to pass as *fully valid*' (Kelley 1978). It is clear from this that Marx recognised that there were limitations on our understanding of society but that he did not accept that this licenced uncritical acceptance of laws and practices that had been inherited from the past. Marx was not, however, denying the importance of the connection between the past and present or indeed the present and the future. This was already clear in his outline of historical materialism in *The German Ideology* (1845–1846). It was set out more clearly in a letter written to Annenkov in 1846 in which Marx argued that men were not free to choose this or that form of society:

> [M]an is not free to choose *his productive forces* – upon which his whole history is based – for every productive force is an acquired force, the product of previous activity …. The simple fact that every succeeding generation finds productive forces acquired by the preceding generation and which serve it as the raw material of further production, engenders a relatedness in the history of man
>
> (Marx 1982: 96)

For Marx, however, recognition of the continuity between past, present and future was not a reason for inaction. On the contrary, development in one part of the system created the need for changes elsewhere:

> Man never renounces what he has gained, but this does not mean that he never renounces the form of society in which he has acquired certain productive forces. On the contrary. If he is not to be deprived of the results obtained or to forfeit the fruits of civilisation, man is compelled to change all his traditional social forms as soon as the mode of commerce ceases to correspond to the productive forces acquired.
>
> (Marx 1982)

Marx's view on the nature of the choices open to mankind finds echoes in Joseph Schumpeter's *Capitalism, Socialism and Democracy*. There Schumpeter argues that:

> Mankind is not free to choose ... things economic and social move by their own momentum and the ensuing situations compel individuals and groups to behave in certain ways whatever they may wish to do- not indeed by destroying their freedom of choice but by shaping the choosing mentalities and narrowing the list of possibilities from which to choose.
>
> (Schumpeter 1947a: 129–130)

2.6 KNOWLEDGE, GOVERNANCE AND POLICY

In *Dialogues Concerning Natural Religion*, Hume used an argument based on Mandeville's example of a sailing ship to call into question the view that the apparent order of the world necessarily implied the existence of a god or grand designer.

> If we survey a ship, what an exalted idea must we form of the ingenuity of the carpenter who framed so complicated, useful, and beautiful a machine? And what surprise must we feel, when we find him a stupid mechanic, who imitated others, and copied an art, which, through a long succession of ages, after multiplied trials, mistakes, corrections, deliberations, and controversies, had been gradually improving?
>
> (Hume 1779, part 5)

Hume suggested that, rather than postulating one grand designer, one should consider the possibility that the world was the result of efforts by several 'lesser' gods. If a great many men could join together to build a house or ship, to found and develop a city or to create a commonwealth, there was no reason why several gods could not combine in designing and making a world. In other words, the world itself was the product of trial and error by many over a long period of time (Glacken 1967; Alter 2008).

Hume's challenge to arguments for the existence of a grand designer has been appropriated in modern times for a different purpose, namely to challenge arguments for forms of state intervention in the economy. Thus, for instance, Lorenzo Infantino argues that due to an extremism of reason which has lost 'the awareness of its own limits' we moderns have moved from the idea of an intentional order attributable to God to that of an intentional order attributable to the designs of man (Infantino 1998: 1). Infantino cites a passage from F. A. Hayek's *Constitution of Liberty* in which having commented on the subtlety and complexity of the institutions of law, Hayek contended that such institutions are the products of evolutionary processes and have not been deliberately designed. As Hayek put it:

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> If it had been deliberately designed, it would deserve to rank amongst the greatest human inventions. But it has, of course, been as little invented by any one mind as language or money or most of the practices and conventions on which life rests.
>
> (Hayek 2011: 216)

There is no issue with Hayek on this point of the single designing mind. However, as Jacob Viner pointed out in his review of Hayek's book, correct statements about strong cases become a problem when they are applied more generally. Viner presciently challenged Hayek's implicit characterization of government as a single, unified entity arguing that government itself may be 'an institution which is in large degree a spontaneous growth, inherently decentralised, experimental, innovating, subject not only to tendencies for costly meddling but also to propensities for inertia and costly inaction' (Viner 1961: 235).

The tendency to consider the state or policy maker as a single actor, which was commonplace in post-war welfare economics, is no longer the mainstream view (Flanagan et al. 2011). For example, Schmitter (1985: 33) refers to the state as 'an amorphous complex of agencies with ill-defined boundaries, performing a variety of not very distinctive functions' while Hay (1999) argues that the state 'comprises a diverse array of specific, but none the less interdependent, agencies, apparatuses and institutions'. These institutions enjoy some degree of latitude which is reflected in their structures, practices, procedures and modes of conduct.

Arguments relating to the proper location of decision making about economic resources have a long history as is evidenced by the contrasting position taken by James Steuart and Adam Smith in the second half of the eighteenth century. Steuart argued that public spirit is as 'superfluous in the governed as it ought to be all-powerful in the statesman' (Steuart 1767: Vol. 1, 164). The reason for this was that everyone might consider the public interest in a different light and join in the ruin of it by endeavouring to promote its advantages. Steuart who was unashamedly interventionist was making the reasonable point that coherence is a requirement of good policy. Adam Smith agreed that there was need for coherence in policy: 'Some general and even systematical idea of the perfection of policy and law, may no doubt be necessary for directing the ideas of the statesman' (Smith 1976a: VI. ii.2–18). However, he castigated the 'man of system' who imagines that 'he can arrange the different members of a great society with as much ease as the hand arranges the different pieces of a chess-board' (Smith 1976a: VI. ii.2–17). Smith was categorical that, 'in his local situation', the businessman was likely to make much better decisions than the statesman and he warned of the danger of intervention by a statesman or even a council or senate who had the folly to presume that they would do better (Smith 1976b: IV. ii).

Smith was living at a time when few important inventions could be either directly attributed to scientific discoveries or were dependent in some way on scientific insights (Smith 1976b: I.1.9; Mokyr 2018: 217). In such circumstances, the specialist

knowledge of the manufacturer and his own local situation are the most relevant factors in any investment situation. However, as Mokyr notes, localised specialist knowledge could not continue to give rise to sustained technological revolutions. These required the confluence of scientific method and discovery and artisanal knowledge (Mokyr 2018: 274). Smith acknowledged that philosophers and machine makers sometimes had a role in innovation and that there was a case for granting a temporary monopoly to the inventor of a new machine or to a merchant who opened up trade with a remote nation (Smith 1976b: V.i.3 art1).[9] However, he did not address the problems associated with innovative activity in any great detail.

This task was performed by Jeremy Bentham. Like Smith, Bentham advocated reliance on 'the spontaneous exertions of individuals' (Bentham 1843) and already in 1787 he was critical of what he saw as Smith's inconsistency for having proposed a ceiling on the rate of interest in order to discourage excessive risk-taking. Bentham countered that restraints on pecuniary bargains would act as restraints on the progress of inventive industry by making it impossible for those promoting new and inherently risky projects to obtain funds. Governments could rely on the intelligence and inclinations of individuals to promote economic growth. '[N]othing is necessary to be done on its part but to leave them in possession of *the power*, to insure to them *the right* of enjoyment, and to hasten the development of general knowledge' (Bentham 1843: III. 2.iii§23). In identifying measures to hasten the development of general knowledge, Bentham recommended a substantial list of activities which governments might pursue. These included encouraging study of the sciences, instituting prizes for discoveries and experiments, publishing detail of technological processes employed domestically and in foreign countries, publishing price information and the granting of patents for a limited number of years (Bentham 1843) He also argued that, to ensure the right of enjoyment, exclusive privilege was 'absolutely necessary, in order that what is sown may be reaped'. He explained:

> He who has no hope that he shall reap, will not take the trouble to sow. But that which one man has invented, all the world can imitate. Without the assistance of the laws, the inventor would almost always be driven out of the market by his rival, who finding himself, without any expense, in possession of a discovery which has cost the inventor much time and expense, would be able to deprive him of all his *deserved* advantages, by selling at a lower price.
>
> (Bentham 1843)

[9] Recognition of the value of a temporary monopoly as a means of encouraging innovation goes back at least to the early part of the seventeenth century. Misselden referred to patents as beneficial restraints, which provided the inventor of a new art with 'recompense of his industry and encouragement to others to study and invent things profitable to the public' (Misselden 1622: 60).

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Bentham also emphasised that entrepreneurial activity was ultimately valuable for the wider society because successful innovation would be emulated by others who would repeat and multiply the success (Bentham 1818: XIII. 35). Even where ventures turned out to be failures, others might ultimately benefit and could learn from the mistakes made.[10]

Apart from Bentham's contribution, the discussion of the special characteristics of scientific and technical knowledge in late-eighteenth-century Britain was limited with the main focus being on the question of how to prevent leakage abroad of the country's technological knowledge. Restrictions were placed on the migration of skilled artisans and following this the export of machinery was prohibited. Laws restricting the emigration of skilled labour were eventually repealed in 1825 but restrictions on the export of machinery remained in place until the 1840s (Jeremy 1977).

2.7 LAGGING ECONOMIES AND THE TRANSFER OF TECHNOLOGY

Although the classical economists in the early nineteenth century were more aware of technical change than Smith had been in the late eighteenth, the framework of analysis remained one in which growth was conceived as a process of accumulation driven by 'parsimony' (Brewer 1991). As noted earlier, this framework was challenged by a number of authors amongst them, John Rae (1796–1872). Rae did not deny that there was some truth in the accumulation story but he argued that accumulation and innovation did not necessarily go hand-in-hand. An important source of innovation had been neglected, namely 'the progress of arts in other communities and their subsequent transfer to it' (Rae 1834: 76–77). Rae argued that although such transfer was potentially beneficial, it would require costly adaptation. No individual had the incentive to make the necessary investment because, if he did, he would derive no more benefit from his effort than others who copied his innovation (Rae 1834: 56). Rae identified differences in the supply of raw materials, and differences in relative factor prices as factors giving rise to the need for considerable adaptation in the course of technology transfer. An even more serious difficulty was the fact that the information relevant to technology transfer did not exist in a complete and codified form. This meant that the transfer of technology from one country to another necessarily required the migration of skilled personnel, which in turn posed both incentive and selection problems. Rae suggested that these difficulties and his own perception that the majority of men had a strong preference for the tried and tested paths meant that some favourable conjuncture of events was necessary before

[10] But let Titius have found out a new dye, more brilliant or more durable than those in use, let him have invented a new and more convenient machine, or a new and more profitable mode of husbandry, a thousand dyers, ten thousand mechanics, a hundred thousand husbandmen, may repeat and multiply his success: and then, what is it to the public, though the fortune of Titius, or of his usurer should have sunk under the experiment? (Bentham 1787: ch. XIII, 178)

technology transfer could take place. Calamities were favourable to innovation because they disturbed the expected order of events and exposed 'the necessity, or the possibility, of connecting them by some other means' (Rae 1834: 223). However, calamities also diminished the desire for accumulation since they exposed the property of members of society to danger.

Whereas both Bentham and Rae emphasised the public good aspects of technological knowledge, Rae can be thought of as recognising some of the limitations of this perspective, namely the tacitness of technological knowledge and the fact that technology has what Rosenberg described a long umbilical cord and so requires adaptation before it becomes usable in a new situation (Rosenberg 1976: 167). A further limitation was pointed out by Friedrich List in *The National System of Political Economy* [1841]. This was that knowledge was necessary to access existing knowledge.[11] As he put it:

> The present state of the nations is the result of the accumulation of all discoveries, inventions, improvements, perfections, and exertions of all generations which have lived before us; they form the *mental capital of the present human race*, and every separate nation is productive only in the proportion in which it has known how to appropriate these attainments of former generations and to increase them by its own acquirements.
>
> (List 1841: 113)

List attributed to Adam Smith and his followers a cosmopolitan view of political economy which advocated free trade but failed to take adequate account of differences between nations.[12] List was not anti-free trade per se but against free trade in a context where some nations had fallen behind others so that their industrial development would be stifled by foreign competition. This, and the fact that new industries involved considerable risk meant that there was a case for providing them with a temporary monopoly in the domestic market. The interests of consumers would be protected by the gradual introduction of domestic competition and the eventual restoration of free trade (Shafaeddin 2000).

In his introduction to the 1909 edition of *The National System*, J Shield Nicholson drew particular attention to the difference between List's view of capital and that which had been attributed to Adam Smith. While Smith, himself, had taken an inclusive view of capital including within it the natural and acquired abilities of the inhabitants, his successors took a much narrower view focused entirely on material forms. As a result, the importance of immaterial productive forces and powers dropped out of view. List argued that mere accumulation of fixed capital was not enough. 'All expenditure in the instruction of youth, the promotion

[11] For a detailed discussion of the relevance of this issue see the chapter by Kealey and Ricketts in this volume.

[12] As Shield Nicholson (1909) and Watson (2012) have pointed out, List's criticisms of Smith are not altogether reliable. However, whereas some of List's criticisms are wrong as applied to Adam Smith, they are often just as applied to his followers.

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of justice, defence of nations, &c. is a consumption of present values for the behoof of the productive powers' (List 1841: 112). This was not all, a long list of institutions, conventions, innovations and reforms were, List argued, rich sources of productive power. These included: the Christian religion; monogamy; abolition of slavery and of vassalage; hereditability of the throne; the introduction of the principle of freehold property, and of means of transport; and invention of printing, of the press, of the postal system, of money, weights and measures, of the calendar, of watches, and of police (List 1841: 113). Elsewhere in Book II, List noted the contribution of financial sector, the importance of science and scientific education as well as the importance of infrastructure such as roads and waterways. List summarised:

> The nation derives its productive power from the mental and physical powers of the individuals; from their social, municipal, and political conditions and institutions; from the natural resources placed at its disposal, or from the instruments it possesses as the material products of former mental and bodily exertions (material, agricultural, manufacturing, and commercial capital).
>
> (List 1841: 181)

The validity of List's distinction between values of exchange and productive powers has been questioned on the ground that the only way to measure the strength of productive powers is to measure the values in exchange of what they actually produce (Winch 1998: 308). However, both the theoretical and empirical literature on economic growth provide strong evidence to support Schumpeter's contention that the gains from technical progress greatly outweigh those that may be achieved through allocational efficiency. As Schumpeter put it:

> A system ... that at every point of time fully utilizes its possibilities to the best advantage may yet in the long run be inferior to a system that does so at no given point of time because the latter's failure to do so may be a condition for the level or speed of long run performance.
>
> (Schumpeter 1947a: 83)

Intimations of several aspects of modern innovation theory can be traced to List. His recognition that knowledge is required to access and use 'the mental capital of the human race' is nowadays discussed under the heading of absorptive capacity (Cohen and Levinthal 1990). List is also acknowledged as a pioneer of the concept of national innovation systems, one of the main frameworks used for the analysis of modern science, technology and innovation policy (Freeman 1995; Lundvall 2010; Schot and Steinmueller 2018).

2.8 THE INNOVATION ECOSYSTEM

The policy issues which had been identified by the mid-nineteenth century have not been assuaged by the passage of time. By the mid-twentieth century, it was

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increasingly clear that scientific knowledge was important for innovation and growth and questions were posed as to how greater scientific effort might be elicited in market-based economies (Elder and Fagerberg 2017). In an influential paper published in 1962, Kenneth Arrow argued that a free enterprise economy had a tendency to underinvest in invention and research because it is risky, because the product can be appropriated only to a limited extent and because of increasing returns in use. Furthermore, even if a firm did manage to engross the value of its inventive activity, there would be underutilisation of that knowledge compared with the ideal. This analysis, usually referred to as the market failure framework, provided support for three policy approaches: (i) state support for basic research, (ii) use of subsidies to encourage additional research and development (R&D) in the private sector, and (iii) strengthening of intellectual property regimes (IPR).

The market failure framework proved to be resilient and able to identify if not resolve new problems arising from changes in technology and industry structure. However, it has also attracted criticism from a variety of directions. Those concerned about the efficacy of government intervention in the innovation process argued that policy makers lack the information that would enable them to intervene optimally or even effectively. They also argued that policy interventions encourage rent seeking and various forms of unproductive activity (Kreuger 1974). Others maintained that the view taken of innovation in the market failure framework is overly narrow and that a broader systems perspective was required to account of some features of the knowledge economy. These were : (i) that rather than being a pure public good, knowledge is sticky and hence linked to a variety of geographical, organisational and cultural factors (von Hippel 1994); (ii) that the ability to absorb and develop new knowledge depends on prior acquisition of capabilities which are themselves linked to a variety of social capabilities including education, an entrepreneurial outlook and the nature of wider supportive institutions (Cohen and Levinthal 1990); and (iii) that rather than being a linear process in the form of flow from science to R&D to commercialization, knowledge is generated through interactions between users, including end users, and producers at various administrative and geographical levels (Schot and Steinmueller 2018). This broader systems perspective on innovation has the merit of focusing policy attention on a wide range of relationships and emergent organisational forms operating at different geographical levels: international, national and local. Advocates of the national perspective emphasise that countries differ not only in their historical experience, language, culture and legal systems but also in their industrial structure, in the role of the public sector, in their education and training systems, and in the structure of their financial and R&D sectors. Others, emphasising the stickiness of knowledge and the importance of interfirm interaction focus their attention on regions and industry clusters. Advocates of the systems frameworks do not deny that imperfect information and even lack of information is a problem, but they argue that the right way of thinking of industrial/innovation policy is as a discovery process – one where economic actors including

firms and the government learn about underlying costs and opportunities and engage in strategic co-ordination (Rodrik 2004).[13]

There is a large literature on the relevance of the national systems of innovation framework to developing countries (Nelson 1993: part III; Kim 1999; Cimoli et al. 2010; Yip and McKern 2016). The perspective also found favour in more advanced industrial countries due to its relevance for the maintenance of the competitive advantages of domestic firms in an era of increasing globalisation (Lundvall 1992, 2016; Nelson 1993; Freeman 1995; Porter 1998; Shot and Steinmueller 2018). However, arguments about the nature and extent of policy interventions did not go away but re-surfaced as arguments about the merits of level playing fields as opposed to discretionary policy. As Lundvall (2016) notes, one drawback of the national systems framework is that the precise implications for policy are difficult to identify. This is partly because most studies are country-specific but, even where comparative analysis has been carried out it often lacks a common theoretical framework.

The Marshallian industrial district as updated by Beccatini and Michael Porter's cluster–based approach shares many features of the systems-based approach (Becattini 1990; Porter 1998).[14] Porter sees the clusters as geographic concentrations of companies and institutions in a particular field. These may include suppliers of specialised inputs and infrastructure; channels to customers; manufacturers of complementary products; and companies in industries utilising similar skills, technologies or other inputs. Clusters involve both competition and co-operation – the former is necessary to prevent stagnation and drive innovation whereas the latter opens up opportunities for the provision of scale-sensitive or collective goods including research, training and testing facilities; the collection of information; the organisation of trade fairs; and managing purchasing consortia.

Overlapping with the notion of industry cluster is Pisano and Shih's (2012) concept of the industrial commons. Commons is seen as consisting of webs of technological know-how, operation capabilities and specialised skills that are embedded in the workforce, competitors, suppliers, customers, co-operative R&D ventures, and universities and often support multiple industrial sectors (Pisano and Shih 2012: 13). Pisano and Shih emphasise that industrial commons are a delicate

[13] Carlsson and Stankiewicz (1991) emphasise that the boundaries of technological systems may or may not coincide with national borders and may vary from one techno-industrial area to another.

[14] Mention should also be made of Porter and van de Linde's (1995) article which suggests that environmental regulation could induce innovation of clean technologies and in doing so make production processes and products more efficient. The article has spawned a huge literature the main contours of which are reviewed in Ambec et al. (2013). While the Porter hypothesis can be regarded as part of the market failure/organisational failure literature that affects all innovation, it has opened up important discussions about whether a Pareto superior global equilibrium fulfilling environmental and other objectives might exist and how it might be reached in practice.

ecosystem which can easily unravel if the private returns of some elements drop below a threshold (Pisano and Shih 2012: 60). Their position is best understood in the context of the arguments which suggest that economies such as that of the United States can benefit from concentrating on R&D and design while subcontracting more routine work to low-wage international providers. This may work in some industries but Pisano and Shih argue that in many, product innovation cannot be readily separated from manufacturing. In such industries, outsourcing firms may be undermining not only their own capacity to innovate but also that of the wider ecosystem. Interestingly, Pisano and Shih's proposed remedies in the face of decline have echoes of List – not in terms of protectionist trade policies but in terms of a clear focus by firms on building capabilities and on appreciating the value of belonging to a strong industrial commons (Pisano and Shih 2012: 105). Likewise, they propose that government should commit to strengthening the scientific and technological foundations of the commons and the development of human capital at all levels (Pisano and Shih 2012: 125–133).

While Pisano and Shih and Porter emphasise the importance of tacit knowledge and localisation in the innovation process, others explore situations in which a firm's ability to innovate depends more directly on assets that it does not own (Iansiti and Levien 2004; Adner 2006; Moore 2006). These authors emphasise not just spillovers from other firms in the ecosystem but situations where any given firm's innovations rely on complementary innovations by some other firms with no one firm possessing all the specialised knowledge and resources required for innovation (Moore 2006). These ecosystems may arise as a result of disaggregation of departments in existing firms or be developed by entrepreneurial leaders who as Moore (2006) puts it 'declare a "space" for invention and investment'. Either way, mechanisms for co-ordination are required. In some cases, these are provided by a lead enterprise or platform where the latter is described as any combination of hardware or software that provides standards, interfaces and rules and support that enable providers of complements to interact with each other and or users (Cusumano and Gawer 2002; Kay et al. 2018; Teece 2018). Apple is regarded as an example of a lead firm. Wikipedia may be taken as an example of an ecosystem/knowledge commons/community of practice without a key player. Wikipedia operates without a centralised review of contributor actions but it is also an evolving sociotechnical system that employs managerial hierarchies, protocols and automated editing systems to orchestrate human and non-human contributors (Niederer and van Dijck 2010). The important point here is that co-ordination mechanisms are always required, though they may take many different forms and evolve in various ways. In their study of innovation by open source software communities, Mateos-Garcia and Steinmeuller (2008) note the tendency to see knowledge-related communities with voluntary organisation of effort and traditional, hierarchically managed organisations as the only alternatives available for organising the production of knowledge in an online context. They suggest, instead, a continuum of possible structures whose shape is

determined by the way in which rules of entrance and participation are defined and put into practice.

As has long been recognised, standardisation reduces transaction costs and facilitates the division of labour. The digital economy is no exception; technological standards provide the platform on which rival firms build their product and service offerings (Cusumano and Gawer 2002; Teece 2018: 1380). These standards may emerge as a result of market competition especially in downstream applications. They may also be developed by means of formal processes undertaken by national and international standard setting organisations most of which operate on a not-for-profit basis. Once provided, standards facilitate entry and competition and allow for autonomous innovation without the need for active co-ordination as long as the relevant standards for their module are met (Teece 2018: 1380–1382). Teece distinguishes between standard setting, which is concerned primarily with achieving uniformity and compatibility, and standard development, which takes account of the potential for further innovation not just at the level of the individual actors in the ecosystem but also at the architectural level. This issue of standard development has recently arisen with respect to the Internet itself. It is suggested that the existing protocols are not adequate to underpin new developments such as self-driving cars and the Internet of Things and that a more efficient address system is required to support emerging technologies (Gross and Murgia 2020).

Whereas Teece (2018: 1381) discusses standard development as a technical selection process which begins with firms investing large sums of money in R&D, Potts (2018) and Allen and Potts (2016) focus on information pooling and emerging standards at earlier stages in the innovation process. They postulate a stage zero innovation commons involving peer production of the information required to discover opportunities from which to develop markets, firms and industries. According to Potts (2018: 1026), 'innovation originates in a prior state of non-market coordination among proto entrepreneurs and technology enthusiasts who develop governance rules to facilitate co-operation'. Likewise, emphasising the entrepreneurial function, Malerba and McKelvey (2020) note that knowledge and business opportunities do not exist a priori but instead emerge and come together through the actions of entrepreneurs. In the process, there may be a demand for new knowledge as well as the creation of conditions in which it may emerge. Some of the knowledge relevant to innovation is codified or embodied in artefacts and conventions and institutions but much of it exists as what we nowadays call human capital (Foray 2004). In a situation where there is no innovation (Schumpeter's circular flow), the specialised knowledge is co-ordinated by means of hierarchies and normal market arrangements. These, however, are insufficient when what requires co-ordination is not yet fully known because the new thing is still in the process of creation. It is the need for co-ordination of this type that gives rise to Schumpeter's entrepreneurial function (Schumpeter 1961). It involves bringing together fragmented knowledge and creating the conditions for this knowledge to

be actualized in things, in services or in social constructs. The process is likely to be ongoing in time and experimental. Different participants and governing structures may be required at different stages (Dedehayir and Seppänen 2015).[15] It may, therefore, involve a complex and ever-changing array of institutions, standards, conventions and resources to facilitate information exchanges and co-operation by different actors including firms, governmental and non-governmental organisations, education and research establishments, professional bodies, voluntary associations and individuals.

While innovation adds to our stock of knowledge, ultimately our interest must be not just in adding to knowledge but also in its efficient use. The peculiar properties of knowledge mean that these two objectives may be both contradictory and indissociable as Foray (2004) notes. Knowledge is non-subtractable in consumption but at the same time universal access may be an obstacle to its private production. Knowledge is also cumulative so that collective progress may be inhibited by intellectual property rights provided to encourage private production. There are no simple governance solutions to these dilemmas, but the solutions generated in any conjuncture have the potential to be beneficial for society and to enhance the possibilities for further progress.

In the concluding pages of his *The Origin of Species*, Darwin wrote that the study of natural history would become far more interesting when we no longer look at organic things as a savage looks at a ship but instead see every production of nature as one which has a history in the same way as we look at any great mechanical invention as the summing up of the labour, the experience, the reason and even the blunders of numerous workmen (Darwin 1859: 485–486). In this chapter, it is suggested that this perspective might fruitfully be recaptured for knowledge itself. Doing so enables us to see that knowledge is cumulative, tacit, and embedded. It allows us to understand that it is a social product, that it is developed and transmitted socially in the context of a division of labour which makes transmission possible while also shaping access to existing social knowledge. It enables us to appreciate that while the future path of knowledge cannot be predicted with any certainty, it is tethered to the present and not arbitrary and is therefore shaped by present choices. Not least, it forces us to recognise the limitations of our own rationality while appreciating the coherence of what has been communally achieved.

[15] A study of asynchronous design by Delemarle and Laredo (2008) shows that while identifying a space for invention and innovation is important, it needs to be accompanied by standardization if non-hierarchical development of a field is to succeed. They found that European-financed support for conferences and research involving both universities and firms helped to build the credibility of the asynchronous design field as a basis for breakthrough innovation. However, in this case, independent research groups pursued different niche projects and because of this were unable to converge on a dominant architecture or design tool. As a result, no market could be shaped and no product class standards emerged.

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