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Cultural entrepreneurs and the origins of modern economic growth*

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The concept of entrepreneur is a central one in economic history. The definition of entrepreneur is extended here to include 'cultural entrepreneurs' and show how they can be integrated into the new modern economic interpretation of 'culture' as agents who change the beliefs of others. This concept can help us understand one of the central dilemmas of modern economic history, namely how the new institutional economic history can be deployed to understand modern economic growth. Cultural changes in the early modern age led to institutional changes that made Europe more friendly to innovation. In that process, two English figures can be seen as central, Francis Bacon and Isaac Newton. The essay shows how they meet the definition of a cultural entrepreneur and how their work coordinated and focused cultural change that was instrumental in preparing the ground for the Industrial Revolution.

Keywords: entrepreneurship; institutional economics; Industrial Revolution

1. Introduction

With the growing emphasis on institutions as a central factor explaining differences in economic performance between nations, it has become increasingly clear that *cultural* explanations cannot be far behind.[1] The distinction between cultural factors and institutional ones is not always very clear, and both terms have been used in myriads of inconsistent and even contradictory fashions. Much of this confusion has been sorted out by the seminal work of Avner Greif and my definitions below will rely heavily on his work, but differ from it in some aspects.[2] The fundamental distinction I will maintain is that institutions refer to systems of formal and informal rules and incentives that govern the allocation of resources and constrain economic behaviour in an economy, whereas culture refers to a system of beliefs, values and preferences that shape these institutions. The question that underlies this paper is what the individual takes for given and what is it that he or she can make choices

The article is based on my Eli F. Heckscher memorial lecture given in Stockholm, October 2011. Some of the material below is adapted from my **The Cultural Roots of the Modern Economy** (2012) and related papers.

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[1]For a good summary of the current literature on the importance of institutions in economic history. See Acemoglu et al., 'Institutions' (2005). Acemoglu/Robinson, *Why Nations Fail* (2012).

[2]Greif, 'Cultural Beliefs' (1994). Greif, *Institutions* (2005).

over. Greif notes that individuals take institutions as given to him/her. Society sets up rules and norms and these will impose a system of rewards and costs on each individual that shapes his behaviour, but in principle these cannot be changed by a single agent any more than the prices a consumer faces in a competitive market. Culture is different. Each individual faces a 'menu' of beliefs and preferences that he or she can choose from: political and social values, personal preferences and even scientific and metaphysical theories (including religion). Such choices can be made during an individual's lifetime, and while they are made infrequently, there is no real constraint on the number of times an individual can change his beliefs and preferences.

As Spolaore and Wacziarg have recently stressed, socialisation by one's parents and immediate environment imply that the default option of each individual is to be like their parents: the children of Jewish parents are likely to become Jewish themselves, to dislike pork and to value human capital and motherhood.[3] However, at some point in their lives they will face choices whether to renounce this default or to remain loyal to it. Economists cannot predict how and when such choices are made, but what seems clear is that the more options an individual has and the larger the 'menu' of cultural choices she is faced with, the more likely he is to deviate, other things equal, from the default option. We may see more common and more rapid 'cultural change' and eventually changes in institutions and economic outcomes.

At the same time, however, the existing institutional structure is instrumental in making such choices. Thus, for instance, the question of whether to remain committed to the traditions of one's fathers is affected by the costs and benefits of converting to another religion, that is, the incentive structure. Thus, people from Jewish families may well decide to convert if this will allow them to choose certain careers closed to Jews. In the end, what counts is observable economic behaviour and decisions, the 'phenotype' in an evolutionary system, which is the outcome of beliefs and incentives, respectively, the 'genotype' and 'physical environment' in which the choices are made.

As Greif noted, each individual makes cultural choices taking as given what others believe.[4] It is not a priori obvious how that affects one's choices. It may affect them positively because conformism implies that there is some social cost associated with deviancy, or because people may reason that if the majority believes a certain thing, there may be wisdom in it (thus saving on information costs). But there can be a reverse reaction as well, with non-conformists perversely rebelling against existing beliefs. What matters for my purposes is that for a small number of individuals, the beliefs of others are *not* given but can be changed. I shall refer to those people as *cultural entrepreneurs*. Their function is much like entrepreneurs in the realm of production: individuals who refuse to take the existing technology or market structure as given and try to change it and, of course, benefit personally in the process. Much like other entrepreneurs, the vast bulk of them make fairly marginal changes in our cultural menus, but a few stand out as having affected them in a

[3]Spolaore/Wacziarg, 'How Deep Are the Roots?' (2011).
[4]See Greif, 'Cultural Beliefs' (1994). Greif, *Institutions* (2005).

substantial and palpable ways.[5] In recent years, economists have become increasingly interested in the way in which some influential individuals affect the beliefs and preferences of others. Thus, Glaeser has shown how certain political entrepreneurs, or 'entrepreneurs of hate' convince others to dislike some group in a way that may benefit them.[6] In a very different context, Acemoglu and Jackson show that leadership of 'prominent agents' can affect future social norms whether to be more or less cooperative (in the sense of generalised trust).[7] In this paper, I want to focus less on the relationships between agents and others and more on the relationship between people and their natural environment and thus in the end how beliefs affected technological change.

Cultural entrepreneurs, then, are defined as individuals that add to the menus from which others choose. How, exactly, they themselves arrive at their novel ideas is in the final analysis unknowable, but usually they build upon existing but diffuse notions, and formulate them in a sharp set of propositions or beliefs, which serve as a cultural Schelling focal point to their contemporaries. In that sense they create something new. They also build, however, on deeper pre-existing pressures that cause people's views to change from those they were socialised with, possibly because there is a dissonance between those views and certain aspects of the social or physical reality as people perceive it. Yet because such dissonances are evolving independently, they tend at first to be diffuse and require coordination and standardisation. Thus, for instance, we can easily document the growing disenchantment of Europeans with the established Church in the fifteenth century, but it required cultural entrepreneurs such as Luther and Calvin to create a coherent new alternative. Marx, too, lived at a time when the prevailing interpretations of society were no longer consonant with a new industrial and urban reality, and appeared in the wake of a myriad of disparate socialist ideas, some of which were 'Utopian' while others claimed to have scientific value, and which he standardised into a new Marxian orthodoxy. To repeat: cultural entrepreneurs are the creators of epistemic focal points that people can coordinate their beliefs on. What matters here above all is *persuasion* – the ability of a cultural entrepreneur to induce others to abandon existing views and to assume his beliefs. Yet this can only succeed if the 'distance' between pre-existing and the new beliefs is not too large.

The concepts and processes I identify for this will serve me as a tool to make some progress on what I consider to be the *deep dilemma* of economic history in our age. The dilemma is created by the problem that institutions, identified from Douglass North's seminal work onward as a major driver of economic development, are a powerful element in explaining the kind of growth identified by Smith as gains from specialisation and trade. Better institutions that defined property rights, enforce contracts and resolve disagreements between agents deepen and broaden markets

[5]The concept of 'cultural entrepreneur' was inspired by Greif's recent work on morality and his innovative concept of' 'moral entrepreneur'. He notes that:

> moral entrepreneurs are individuals with new moral visions who seek to gain followers. When they fail, they enter the history books, if at all, as anarchists, rebels, false prophets, cult leaders, and heretics. When they win, they write the history book'. [Greif, 'Theory' (2012), 31]

[6]Glaeser, 'Political Economy' (2005), 46, 52, 62.

[7]Acemoglu/Jackson, 'History, Expectations and Leadership' (2011).

through the lowering of transactions costs and barriers to trade, and in that way helps to improve allocations and makes the economy more efficient. These institutions involved the emergence of trust, reputation mechanisms and other private-order institutions that made markets possible. They also involved the rise of modern and inclusive political institutions that served as third-party enforcers, be they 'the modern State' as North has argued or, as Gelderblom has recently argued, local and municipal authorities.[8] There is no question that much economic growth in the premodern age, spasmodic and reversible as it may have been, was based on such gains from trade and specialisation resulting from these improved institutions.

Yet while institutional changes were at the centre of the story of economic growth before 1750 and have remained important during the subsequent quarter millennium, they do a less persuasive job in explaining technological progress, which became the backbone of modern economic growth during the Industrial Revolution.[9] To phrase it differently, the Talmud distinguishes between matters, between people and others and between people and *makom*, a somewhat unusual name for the deity meaning literally 'place' and practically can be seen as one's physical environment.[10] To some extent, the same institutions that supported Smithian growth before 1750 were instrumental in supporting the accelerating rate of technological progress after. Some institutions such as the protection of intellectual property rights in some form were of considerable importance. But in and of itself that was not enough. It is easy enough to think of examples of highly commercialised and monetised economies that still were unable to cross the threshold of the self-sustaining growth of useful knowledge. The acceleration of technological progress required a smooth and low-cost interaction between propositional knowledge and prescriptive knowledge, and the weakening of political resistance to technological progress by entrenched incumbent interests.[11]

In other words, what was needed for something like an Industrial Revolution was more than just well-functioning markets and the institutions that supported them. It required a determined programme reflecting the willingness to study nature in order to improve material conditions or 'Man's estate' (as Francis Bacon called it). It also required a healthy dose of scepticism (not to say disrespect) towards the received wisdom of previous generations and civilisations. The commitment to this research agenda required a different set of cultural elements that governed games against nature as opposed to other players. Yet they were not only games against nature, but they also involved differences in attitudes towards other groups in society. Above all, they required a rapprochement between the class of highly skilled artisans, engineers,

[8]Gelderblom, 'Cities' (in press).

[9]This issue is particularly salient in the literature that compares China with Western Europe. In an important paper, Keller and Shiue show that trade-supporting institutions in China around 1750 were not much inferior than they were in much of Western Europe and that the allocation of resources (as measured by price cointegration) were of comparable magnitude. But they then link this to the onset of the Industrial Revolution without relating to the 'Needham Question', which asks why science in technology in China fell behind Europe at some point after 1600. Shiue/Keller, 'Markets' (2007).

[10]This distinction can also be found in much of the Enlightenment literature, such as d'Alembert's work, where he distinguishes between the Science of Man and the Science of Nature. d'Alembert, *Preliminary Discourse* (1995), 54–55.

[11]I have argued for this case at length in Mokyr, *Gifts of Athena* (2002).

mechanics, agricultural experts, physicians, coal viewers and similar professionals on one side and a different class of people, 'natural philosophers' as they were known at the time: mathematicians, astronomers, natural historians and experimentalists. They also required the changing of the agenda of natural philosophy towards subjects with potentially productive applications.[12] A distinguished historian of science complained that, oddly enough, his colleagues had rarely addressed the issue 'what it was about the new science [of the seventeenth century] that made it adaptable to technological change'.[13] Yet science, in its more strict definition, was not the match that lit the fires of the Industrial Revolution in its early stages, although it was increasingly the fuel that kept the fires of progress burning. Rather, the dynamics of both science and technology were driven by deeper factors that determined the attitudes and beliefs of the crucial elites that dominated both.

What I will argue below is that in the decades before the Industrial Revolution, a number of key players changed the cultural milieu in which technology operated, and enhanced a *mentalité* that was more conducive to the application of useful knowledge to production. These cultural changes prepared their society for a different economic dynamic, one in which technology increasingly occupied centre stage in the growth of the economy. This culture, to be sure, pertained to a relatively small segment of society. It was not 'popular culture' that changed, but the culture of a thin elite of intellectuals, physicians, natural philosophers, experimentalists, engineers and professionals and amateurs who devoted their lives to 'experimental philosophy'. Mixed in with them was a smattering of highly skilled artisans. As Hooke noted, 'this newfound world must be conquered by a Cortesian army, well-disciplined and regulated, though their numbers be but small'.[14] Yet this was, as we know now, nothing exceptional. The British Industrial Revolution was created by the attitudes and aptitudes of a small sliver of British society: in this paper, I will be concerned with attitudes, although there is no doubt that aptitudes were at least as important.[15]

2. Cultural entrepreneurs

In the marketplace of ideas, individuals with new ideas connect with potential 'customers' and try to *persuade* them of the merit of their idea. An idea here is simply some well-defined intellectual unit that is either a description of reality or an interpretation thereof, a logical construct, or a set of instructions or recommendations. It includes anything between new techniques proposed by inventive artisans, William Harvey's belief in the circulation of blood, and Luther's 95 propositions. The notion of a 'market for ideas' is not new.[16] It raises hard questions about a market in

[12]A good description of such activity in Elizabethan London is in Harkness, *Jewel House* (2007).
[13]Westfall, *Scientific Revolution* (2000), 50. The glaring exception to Westfall's statement is the work of Margaret Jacob, above all Jacob, *Scientific Culture* (1997).
[14]Cited by Hunter, *Establishing the New Science* (1989), 233.
[15]For more details, see Meisenzahl/Mokyr, 'Rate' (2012). Mokyr, *Enlightened Economy* (2009), 57–58, 121–122.
[16]See for instance Gans/Stern, 'Product Market' (2003). In their context, the market of ideas concerns more concrete markets in intellectual property rights, Mokyr, 'Market for Ideas' (2006).

an entity on which property rights are not well established and which does not even follow the laws of arithmetic. If individual x persuades his neighbour of proposition y, what is to stop the neighbour from 'selling' it to a third person? The answer is basically 'nothing', but a successful cultural entrepreneur has the capability of having his name associated with the new idea so that y and x become a dyad much like Boyle's Law or a Poisson process, and thus while he does not 'own' the new idea (in the sense that he can exclude others), he is credited with it and may, therefore, gain in terms of reputation. It is significant, however, that the person who receives credit for an idea is not always the person who is historically the *first* to discover or enunciate it, but often the one who manages to market it most effectively in the market for ideas.[17] Here, too, the analogy with entrepreneurs in the business world holds up.

The transaction of persuasion can take place at arm's length between individuals who do not know each other, but in this period most of the time it occurred through social networks of mutually acquainted scholars, especially through personal contact, correspondence and publication.[18] Buyers selected from a 'menu' of new ideas, creating a Darwinian process of 'artificial selection'. If the seller managed to persuade the buyer, a 'sale' had taken place. For the seller this may mean a book sale or a lecture fee, but on the whole the gain from selling an idea to many buyers is reputational, fame often measured by such indicators as the number of citations or graduate students attracted. One question is what motivates cultural entrepreneurs; unlike entrepreneurs in the world of production, there is little expectation of great wealth and political power. Yet there can be little doubt that, at least for those who were ex post successful, there were many satisfactions, both in terms of reputations, which were often correlated with patronage, and the personal satisfaction of seeing one's views widely adopted. Thus, many of the greatest scientists of the period of the Scientific Revolution found secure patronage jobs as councillors, court-scientists or in various sinecures and were honoured in their own lives.[19] Reputations were desirable in and of themselves, yet the patronage model has enough exceptions to it to underscore that the search for patronage was not all there was to a life spent in scientific research. Examples of wealthy individuals such as Boyle or those with more remunerative day jobs such as Leeuwenhoek make this point. In any case, the market for ideas is a Schumpeterian construct in which competition is less between similar producers competing by price as between old and new techniques and commodities competing by quality.[20]

The modus operandi of many cultural entrepreneurs differed, of course, from period to period as well as from the cultural sphere in which they operated. Mohammed and Adam Smith at first glance had little in common. All the same, we

[17]This was pointed out by Stephen Stigler, and is known as 'Stigler's Law'. Appropriately enough, Stigler has attributed its original discovery to Robert K. Merton; Stigler, *Statistics* (1999).
[18]Collins, *Sociology of Philosophies* (1998), 523–569; see also Grafton, *Worlds* (2009), 9–34.
[19]This was stressed by Paul David, who has linked the rise of modern 'open science' to the competition for patronage based on reputation effects; David, 'Historical Origins' (2008).
[20]As Schumpeter noted in a widely cited passage:

> In capitalist reality, as distinguished from its textbook picture it is not [price] competition which counts but the competition from the new commodity, the new technology [. . .] which strikes not at the margins of the profits of the existing firms but at their [. . .] very lives. [Schumpeter, *Capitalism* (1950), 84]

can see certain similarities. What determined their success was not only content but also rhetoric: the cultural entrepreneur needs to find a formulation and a language that is effective with his intended audience. Moreover, most cultural entrepreneurs operated in concentric 'layers', that is to say, they reached their audience through disciples, apostles, students and epigones who transformed and in some cases translated their messages. At times, of course, these transmissions altered and distorted the teachings of the master. Calvinism as it eventually developed differed significantly from its original formalism, and few will quibble with the statement that twentieth-century Marxism–Leninism bears only a superficial resemblance with the writings of *The Communist Manifesto* and *Capital*.[21] The exact meaning of the writings of cultural entrepreneurs sometimes mattered less than the message that future generations distilled from it. Adam Smith was *not* a prophet of unbridled *laissez faire*, but that seems to matter little to many of his current-day acolytes.

Like all innovating entrepreneurs, cultural entrepreneurs combined an ability to 'read' their market with their original insights, altering the culture by adding items to the menu of cultural choices but by not being so outrageously different as to being ineffectual. Some of them do so by 'sensing' a latent demand: a dissatisfaction within a certain area of cultural beliefs or knowledge, and with the diffuse or incoherent earlier attempts to cope with this reality. They thus set out to alter the beliefs or preferences of others by spreading a more coherent and comprehensible set of cultural elements, but one that can be related to by people 'shopping' in the market for ideas. In so doing, most successful cultural entrepreneurs stand on the shoulders of those who came before them: Adam Smith, perhaps the most successful cultural entrepreneur in economics, was most successful by synthesising and reformulating the economic doctrines he gathered from others.[22] Marx, too, created historical materialism as a hybrid of classical political economy, utopian socialism, Hegelian historicism and other elements. Like in all discussions of entrepreneurship, the counterfactual of what course history would have taken in the absence of some pivotal individual agent remains a matter of speculation. Success was a function of personal characteristics, the capability to inspire a devoted set of followers who would spread the new message, the content of the message and the lucky coincidence of having the right message at the right time.

For cultural entrepreneurs to be successful, there has to be a disconnect between the prevalent cultural elements and some reality that does not quite square with it, much like Thomas Kuhn's cognitive dissonance or what he called 'awareness of anomaly' caused by the accumulation of evidence inconsistent with the current paradigm leading to scientific revolutions. The success of cultural entrepreneurs, however, depends on an environment that is conducive to innovation. If institutions are extremely conservative and conformist, and have the power to repress effectively innovators as heretics and apostates, the risk to which cultural entrepreneurs and their followers are exposed is higher and the likelihood of success is lower. The new ideas proposed by a cultural entrepreneur replace incumbent ideas, and the social and economic benefits accruing to those who control a dominant set of ideas imply

[21]For the statement on Calvinism, see Landes, 'Culture' (2000), 11.
[22]Schumpeter maintained, somewhat unfairly, that 'the *Wealth of Nations* contained no really novel ideas and [...] cannot rank with Newton's *Principia* and Darwin's *Origin* as an intellectual achievement'. Schumpeter, *History* (1954), 185.

that there will be considerable resistance to the new ideas by discrediting them or even using force to suppress them.

Moreover, it is also possible, though uncommon, that the orthodoxy will take a 'if you cannot beat them, join them' attitude and will incorporate some elements of the heterodox ideas in order to preserve its privileges, thus trying to reduce the impact of the cultural entrepreneur. Typically, then, we would see success in conditions where the orthodoxy is inflexible yet at the same time cannot muster enough political power to nip the heresy successfully in the bud. As I have argued elsewhere, the high level of political fragmentation in early modern Europe led to coordination failures among the main conservative powers in Europe, and the ability of intellectual innovators to play one power against another and find safe havens, made it possible for most of them to escape the clutches of repressive regimes and to 'sell' (that is, spread) their views and change the cultural beliefs of substantial segments of the population.[23]

We associate entrepreneurship with innovation, and cultural entrepreneurship is no exception here. Not *all* cultural change occurs through the work of cultural entrepreneurs who tower over others. Much of it, like the changes brought about by entrepreneurs bringing about technical changes, was achieved by the accumulation of small changes through the efforts of countless anonymous agents. At times, cultural change was brought about by people falling halfway between the true giants of cultural change and the almost anonymous agents making marginal changes. The eighteenth-century Enlightenment was the work of many individuals between Locke and Condorcet, who often disagreed with one another on many central points, and the result was a message that was often muddled and confused.[24] Yet a dozen or so names have become famous as 'enlightenment thinkers' and the change was clearly a collective and multinational effort. There was a 'moderate' as opposed to a 'radical' enlightenment (Israel), but there were also national nuances, as well as Pocock's 'Arminian Enlightenment'.[25] The 'early' enlightenment is often regarded as different from the 'late' enlightenment.[26] On most issues, no single cultural entrepreneur towers over the others in the Enlightenment, despite Jonathan Israel's strenuous pleading to place Spinoza in that position.

All the same, the crucial development of the late seventeenth and eighteenth centuries was what I have called the Industrial Enlightenment, the belief in social and human improvement through the accumulation and dissemination of useful knowledge. We can readily identify two cultural entrepreneurs who can make a legitimate claim to have been the focal points of this set of cultural beliefs that arguably had long-term economic consequences. It is important to stress what I am explaining: this is not an argument attempting to explain 'the Enlightenment'. It is an argument about one element of it, one that should be of central importance to economic

[23]See Mokyr, 'Market for Ideas' (2006). The same environment of fragmented and uncoordinated polities was conducive to the emergence of political socialism in the nineteenth century.

[24]John Pocock takes it as 'a premise of this book that we can no longer write satisfactorily of "The Enlightenment" as a unified and universal intellectual movement'. Pocock, 'Barbarism' (1999), 12, cf. Carhart, *Enlightenments of Pocock* (2001).

[25]Israel, *Revolution* (2010). Porter/Teich, *Scientific Revolution* (1991). Pocock, 'Barbarism' (1999), esp. ch. 2.

[26]Carhart, *Enlightenments of Pocock* (2001), rightly asks 'how many enlightenments there were [. . .] I wonder at what point it will become impossible to speak at all of The Enlightenment'.

historians, namely that component that focused on economic improvement through useful knowledge. On this matter, it seems, there was something of a consensus among the people who mattered.

An apparent difficulty with this argument is that many historians have denied the existence of an *English* Enlightenment before the late eighteenth century.[27] If the Enlightenment was such an important component of the intellectual and social background of the Industrial Revolution, how could this be? As I have argued elsewhere at length, this view is based on a rather narrow view of the Enlightenment, seeing it as the presence of intellectuals who criticised the existing order and presented programmes of political and social reform. But social reform and philosophical criticism were not very relevant to what is at stake here and less of a high-priority item on the intellectual agenda of England than on the Continent. What counted in England was what was happening to the application of useful knowledge to 'the arts' – that is, production technology. In this regard, the Enlightenment was inspired and led by two very English cultural entrepreneurs. The keyword here was 'improvement'.[28] Although the term was applied to many things, it was often applied to technology in the sense of increasing efficiency.[29] Eighteenth-century Britain experienced an agricultural enlightenment, a medical enlightenment, and even a transportation enlightenment – all attempts to improve the efficiency and productivity of key sectors.

A critical cultural belief that drives economic growth and that complements the belief in the 'virtuousness of technology', then, is a belief in economic progress. Such a belief has a normative, a positive and a prescriptive component. First, it has to postulate that economic progress is in some sense *desirable*, abandoning any notions that the accumulation of wealth and material goods is somehow sinful or vain. Beliefs that deny the desirability of economic progress are a good illustration of the kind of dilemma that is faced by economists trying to connect culture to economic outcomes. Were earlier beliefs that riches were corrupting and economic growth socially disruptive simply a rationalisation of the inevitable poverty that technology and institutions imposed on economies incapable of growth? Or were they an autonomous force that was causal of poverty by directing the motives and incentives of the best and brightest members of society towards activities that were not conducive to economic growth? Whatever the case, what is crucial is to see how that circle began to be broken in late seventeenth-century Europe by a growing chorus of writers who loudly pointed to useful knowledge that would lead to economic

[27]Venturi, *Utopia* (1971), 132 notes that:

> the very country which was moving towards the Industrial Revolution [was] the only one in which the organization of the Enlightenment did not exist [which] should suffice in itself to call into question the oft-repeated Marxist interpretation of the Enlightenment as the ideology of the bourgeoisie. [See also Robertson, *Unenlightened England* (2000)]

[28]The classic statement here is perhaps Hume's statement in his 'Of Refinements in the Arts' (1760) about 'the spirit of the age' which, in his view, 'roused the minds of men from their lethargy and put them into a fermentation [...] to carry improvement into every art and science', Hume, *Essays* (1985), 271. This sense was quite general in the eighteenth century even if the exact path that would lead to such improvements was of course widely debated.

[29]For a forceful summary statement, see Spadafora, *Idea* (1980), 408–415.

progress and eventually led to the Industrial Revolution and the beginnings of modern growth.

Second, it has to accept the notion that material progress is *possible*, that history shows an upward trend and not just stationary cyclical movements. This belief, of course, required an implicit model of what would have brought about such progress. Such a model emerged in the seventeenth century and became a major force in the age of Enlightenment. It was a model supportive of the ideas that lay behind growing commerce, finance and productivity, even if it was contaminated by the confusions of mercantilism. It was, however, above all a profound belief that useful knowledge could become the engine of economic progress through improving technology. More and more people realised that because useful knowledge was in some sense *cumulative*, it followed that each generation knew more than it predecessors, and thus could draw on a better technology.[30] Other beliefs, somewhat more difficult to sustain, were the innate improvability of human beings and their institutions and the good will of a benevolent Supreme Being.

Third, an *agenda* of policy measures had to be proposed, elaborated and implemented for long-term progress to take place. This agenda became increasingly concrete and detailed in the eighteenth century, and was implemented, in different ways, in the late eighteenth century and then in full in the nineteenth century. It contained two classes of recommendations: institutional improvements to render trade and resource allocation more efficient and government more helpful, and improvements in the arts and sciences meant to increase productivity. These two classes were strongly synergistic and mutually reinforcing.[31] As is common in cultural evolution, they had unintended consequences, because evolutionary processes are almost always messy and imprecise. But in the long run, we cannot understand European economic history after 1750 without them.

These three cultural elements – the desirability of progress, its feasibility and the agenda of how to bring it about through the expansion of useful knowledge – have roots that go back deep into early European history, certainly to the late middle ages and possibly before, but before 1750 they did not produce anything that looked like an Industrial Revolution.[32] But to be effective, they had to be standardised and made persuasive as a coherent doctrine, and they had to be formulated in such a way that disparate and diffuse beliefs could converge on a focal doctrine. The emergence of beliefs in and of itself is never enough to generate economic growth; they have to occur in an environment that is, in some observable sense, conducive to them. It is the combination of new cultural beliefs, proposed by cultural entrepreneurs and promoted and diffused by cultural implementers, within a propitious environment, that explains the sudden change in attitudes and beliefs, which ultimately affected every aspect of society.

[30]One of the great believers in progress, the linguist and biographer William Wotton (1666–1727), made the crucial distinction between areas that were cumulative (such as science and technology) and those that were not (such as rhetoric). His conclusion was that the 'world has gone on, from age to Age, Improving and consequently [...] it is at present much more Knowing than it ever was since the earliest Times'. Wotton, *Reflections* (1694), preface.

[31]For a detailed exposition of the interrelation between technological and institutional improvements, see Mokyr, 'Great Synergy' (2006).

[32]Bury, *Idea* (1955/1932). Pollard, *Idea* (1971). Nisbet, *History* (2008).

How much difference did a few single cultural entrepreneurs make to the economic changes that led to the Industrial Revolution? The dangers of thinking in terms of the effects of single individuals on the course of history have been explored and discussed at great length. The counterfactuals often need to be specified in some detail. Yet much like in any story of innovation, it is convenient and only a little misleading to organise the tale around a few key figures who helped organise, clarify and standardise the work of many, and whose insights (and success) inspired and motivated others.[33] This position does not imply that these individuals were, in some sense, indispensable, nor that they and their work were in some ways an inevitable product of their time and environment. But within those limits, their work and choices left a deep imprint, and much like other great entrepreneurs in history, the details, if not the main tale, would have read a lot different in their absence. At the very least, we may think of them as canaries in the coal mine: an indication that within those societies there were forces to be released to change the culture.

The late Betty-Jo Dobbs pointed out that we choose as our scientific heroes those that have 'contributed to modernity' but that we tend to assume unconsciously that 'their thought patterns were fundamentally just like ours'.[34] My main purpose is not to pick the heroes as they seem today, but rather people who were influential in their lifetime or in the subsequent decades and whose influence, for better or for worse, led to tangible historical outcomes. Yet I am interested in cultural entrepreneurs that above all affected *economic* history through their impact on the agenda of research and technology. For that reason, I will not discuss here cultural entrepreneurs whose impact on beliefs regarding natural philosophy, while enormous, was not directly relevant to the technological developments that led to the Industrial Revolution. Examples of such entrepreneurs would be Copernicus, Galileo and Darwin.[35]

3. Francis Bacon as a cultural entrepreneur

A dated but still useful biography of Bacon refers to him in its subtitle as a 'Philosopher of Industrial Science'.[36] It seems an anachronistic and odd term; 'industrial science' even today sounds almost oxymoronic and in any event has little to do with philosophy. For Farrington, Bacon was not so much the great advocate of an inductive methodology in science but rather someone who had one great idea: knowledge ought to bear fruit in works, science ought to be applicable to industry and it was people's sacred duty to improve and transform the material conditions of life. Bacon's image of how this was to take place sounds uncannily prescient: 'The true and legitimate goal of the sciences is to endow human life with new discoveries

[33]For instance, no economic historian would seriously maintain the notion that had James Watt never been born, there would have been no Industrial Revolution. Yet, as MacLeod has recently demonstrated, following Watt, Britain developed what must be regarded as a hero cult around Watt as an emblem of a set of cultural ideals of what could be done to advance useful knowledge; see MacLeod, *Heroes* (2007).
[34]Dobbs, 'Newton' (2000), 34.
[35]Copernicus, Galileo, and Darwin share the distinction of being fiercely opposed by the religious establishment and overthrowing beliefs that had been held for millennia. See Gaukroger, *Emergence* (2006), 19, who makes the case for Copernicus and Darwin, and Huff, *Intellectual Curiosity* (2011), especially 20, 48–71, making the case for Galileo.
[36]Farrington, *Bacon* (1979).

and resources'. He fully recognised that progress was to be attained by the work of a small elite: 'The overwhelming majority of ordinary people have no notion of this [. . .] perhaps occasionally, some unusually intelligent craftsman [. . .] devotes himself to making some new invention, usually at his own expense'. He complained that most research and development followed an unfocused agenda and thus led nowhere, and that progress has been hindered by an excessive 'reverence for antiquity and by the authority of men who have a great reputation in philosophy and the consensus that derives from them'.[37] In a widely cited short essay, written in 1592, Bacon laid out his view of what knowledge was and what it ought to be. Up to his days, he sighs, technological progress had been the result of small and accidental inventions made by craftsmen. Formal knowledge (what we would refer to as science or propositional knowledge) had to date done very little to discover the underlying natural regularities that governed technology. If man's mind could be raised 'above the confusion of things, where he may have the prospect of the order of nature [. . .] shall he not be able thereby to produce worthy effects and to endow the life of man with infinite commodities?'[38] In the introduction to *The Great Instauration*, Bacon stated that he hoped to establish:

> a true and lawful marriage between the empirical and the rational faculty [. . .] out of which marriage let us hope there may spring helps to man, and a line and race of inventions that may in some degree subdue and overcome the necessities and miseries of humanity.[39]

Bacon's influence was narrow but deep. Unlike the religious entrepreneurs of his time, his thinking only affected a thin sliver of society. Bacon suggested that knowledge was collective, a social phenomenon, to be organised and distributed, and that its purpose was to be applied and used by society for material purposes.[40] The reasons for engaging in the study of nature that Bacon proposed (following a century of progressive thought on the topic) boiled down to the notion that knowledge was not only its own best reward, to be pursued for metaphysical reasons, but that it had the additional potential to improve material life. In one famous aphorism (81) in his *Novum Organum,* Bacon summarises his view: 'The true and lawful goal of the sciences is simply this, that human life be enriched by new discoveries and powers'. He fully realised that this was an elite culture and continues: 'The Great majority have no feeling for this [. . .] But every now and then it does happen that and exceptionally intelligent and ambitious craftsman applies himself to a new invention and as a rule ruins himself in the process'.

The odd thing about Bacon is that he created no science, and was himself a poor scientist. He knew no mathematics and failed to appreciate its importance in the agenda he advocated. He managed to be ignorant of or reject some of the most

[37]Bacon, 'Aphorisms' (1999), 66, 68, 81, 84.
[38]Bacon, *Praise* (1838).
[39]Bacon, *Preface to the Great Instauration* (1620).
[40]As always, there were earlier expressions of his ideas, not always wholly acknowledged by Bacon. One example is the sixteenth century French theologian Pierre de la Ramée (Peter Ramus), with whom Bacon would have agreed that 'the union of mathematics and the practice of scholarly arts by artisans would bring about great civic prosperity'. See Smith, *Business of Alchemy* (1994), 36.

significant scientific advances of his age: Harvey on the circulation of blood, Gilbert on magnets, Copernicus on the solar system and Galileo on physics. It is also the case, as Harkness has argued, that much of what he was pleading for was already taking place on the ground in Elizabethan London, namely the growth of a practical natural knowledge with an attention to utility.[41] In many areas, especially the methods and practical relevance of science, he had many precursors.[42] The Dutch inventor, Cornelis Drebbel, in some ways, was the incarnation of Bacon's hopes, and many of Drebbel's inventions found their way to *New Atlantis*.[43] Any attempt to portray him anachronistically as a prescient advocate of the direct application of science to industry seems misplaced, and much of Bacon's thinking is still an odd blend of alchemical and vitalist natural philosophy with more novel approaches.[44] Yet despite doubts voiced by some historians and philosophers of science influenced by Karl Popper's dismissive attitude, his reputation as a prophet of economic progress (as modern economic historians would recognise) has survived intact.[45]

What mattered in the case of Bacon is not what we think of him today, but the impact he had in the decades that followed his life, in which intellectual processes indebted to him changed the metaphysical outlook of European intellectuals and its scientific and technological elite.[46] His writing was the coordination device which served as the point of departure for thinkers and experimentalists for two centuries to come. The economic effects of these changes remained latent and subterranean for many decades, but eventually they erupted in the Industrial Revolution and the subsequent processes of technological change.

Bacon's work reinforced the trend in the West to build bridges between the realm of natural philosophy and that of the artisan and farmer. This theme is of course not new: Edgar Zilsel and other scholars have emphasised its importance in European development. Inventors and entrepreneurs tried to exploit new ideas in the

[41]Harkness, *Jewel House* (2007), 246.

[42]See an early paper by Stearns, 'Scientific Spirit' (1943). Rossi explicitly claims that:

> Bacon was voicing the general opinion of his age [. . .] when he strove to rehabilitate the mechanical arts [. . .] and planned a history of arts and sciences to serve as a foundation for the reform of knowledge and of the very existence of mankind. Rossi, *Bacon* (1978), 9.

[43]Colie, 'Cornelis Drebbel' (1954), 245–269.

[44]Rossi, *Bacon* (1978), 11–20.

[45]One of the most influential historians of science to explain and support Bacon's role in the rise of economic modernity is Gillispie, *Edge of Objectivity* (1960), 78, who summarised Bacon's vision memorably as a 'program for building an infinity of better mousetraps into a better world'. For a more recent statement in that spirit, see Zagorin, *Bacon* (1998), 97, 121.

[46]One interesting view has been put forward by Barbara J. Shapiro, who has credited Bacon with nothing less than being the 'central agent' of applying the notion of a fact from the realm of law to that of science and technology, Shapiro, *Culture* (2000), 107. Other experts have pointed out that a whole series of applied fields, such as heat, electricity, magnetism and biology were created and 'sanctioned by the Baconian tradition as properly belonging to the cognitive scope of natural philosophy', Pérez-Ramos, *Bacon's Idea of Science* (1988), 35. As Brian Vickers notes, this constituted an enormous expansion and legitimization of the study of nature. Vickers adds that 'Bacon's influence can be traced to a great range of scientific pursuits, including geology, topography, statistics, medicine and much else'. Vickers, 'Bacon' (1992), 516–517.

marketplace by outcompeting their rivals and by profiting in one form or another from restricting others from accessing the same idea.[47] Yet already in the sixteenth century it started dawning on people, as Zilsel noted, that something could be gained from an exchange of information.[48] He pointed out that much of the technological change that occurred before 1600 came from the artisans and craftsmen, who were the 'real pioneers of empirical observations, experimentation and causal research'.[49] In the late sixteenth and early seventeenth centuries, learned authors became interested in their work, and slowly but certainly a symbiosis between prescriptive knowledge and propositional knowledge began to coalesce. In this coalescence, Bacon played a crucial role. As I have emphasised elsewhere, building bridges over the social chasm between *savants* and *fabricants* was a critical feature of European culture, and a war that was won only slowly and haltingly.[50] Yet if technology was to progress in a serious way, the two groups had to respect one another and feel that communication and cooperation could be beneficial. Artisans on their own could improve and tweak existing technology, but some of the greater leaps required deeper scientific insights and bigger imaginations. Bacon also stressed that technological progress would be successful only if it was organised, coordinated, distributed and made accessible. He felt that for that reason the state needed to 'save inventions from the inventors' and knowledge had to moved from the inventors to the collective. In that way, useful knowledge would be both cumulative and accessible.[51]

Interestingly enough, Bacon has been heavily criticised by some modern critics of industrial society. It is ironic, one scholar remarks wryly, that those who were born late enough to have benefitted the most from advances inspired by his insights have heaped the most scorn on his 'disastrously mistaken belief that nature and the creation are ordained for man's benefit and rule'.[52] It is even more striking that economic historians who regard the Industrial Revolution and the subsequent process of economic growth as fundamentally a positive development have never given the Baconian programme much credit for this development. Yet Bacon and his followers planted the seeds of what is now known as the Industrial Enlightenment, and it is hard to think of the Industrial Revolution without the preceding cultural developments that made it possible. Recent writings on Bacon seem to have accepted this, but without explicitly connecting it to later economic growth.[53]

None of this, of course, is to deny that Bacon remained a transitional figure in many ways and that the adoption of his ideas by the eighteenth-century Enlightenment was highly selective. Bacon was no Benthamite. For him useful knowledge

[47]Zilsel, 'Sociological Roots' (1942), 544–560.
[48]One example is the *Accademia Segreta* described by Girolamo Ruscelli in the 1540s, in which academicians mixed with apothecaries, herbalists, gardeners and other craftsmen to study their recipes and techniques. In it, Eamon noted, 'artisans worked side by side with men of leisure and learning', and it serves as a remarkable example of the union of scholars and craftsmen; Eamon, 'Science' (1985), 478. This description may have been more of a Utopian vision than reality, but it is clear that the idea was ripening in Europe even before Bacon.
[49]Zilsel, 'Sociological Roots' (1942), 551.
[50]Mokyr, *Gifts of Athena* (2002), 54, 64–66.
[51]Keller, 'Accounting for Invention' (2012), 242.
[52]Zagorin, *Bacon* (1998), 121.
[53]Thus, for example, Claus Zittel writes, '[Bacon's] philosophy gave birth to the scientific dream of modernity that the advancement of society goes hand-in-hand with the unimpeded development of all technologies'. Zittel, 'Introduction' (2008), xx.

was first and foremost an instrument of state power, not human well-being. Much of his writing, moreover, still bears the marks of an earlier age. Thus, his suggestion that some big advances in science should be kept secret was in direct contradiction to the open science that became the hallmark of the Republic of Letters (and that Bacon himself advocated). As Grafton has noted, much of his utopian book *New Atlantis,* which foreshadowed in some ways modern research institutes, were informed and inspired by church history, rather than by a forward-looking study of useful natural phenomena.[54] It is also true that curiosity and scientific research in Bacon was legitimised by a millenarian justification: the 'Great Instauration' was no more than regaining knowledge that Man had possessed before the Fall. In the end, the 'true end of knowledge' was not satisfying curiosity or material wealth but a 'restitution and reinvesting of man to the sovereignty and power which he had in his first creation'.[55] It is hard to know whether such pious proclamations really were sincere or whether deep below Bacon believed that what really counted was the growth of state power and human control of the environment – arguably in his mind the two were not separable.

What did matter was his view of the role of knowledge: as the foremost student of Bacon in the twentieth century has argued, Bacon saw the interaction of human with their physical environment as a constrained maximisation problem. There were no limits to the possibilities than people could achieve as long as they observed and extended the laws of nature.[56] What matters to the real impact of Bacon as a cultural entrepreneur was what subsequent individuals believed and how such beliefs affected their actions.

After his death in 1626, Bacon's influence expanded through his disciples. The most influential person to take up Bacon's ideas after his death was Samuel Hartlib (1600–1662) who was instrumental in spreading the ideas of Francis Bacon in an ever-widening circle of intellectuals committed to the creation, organisation, standardisation and dissemination of useful knowledge.[57] Hartlib was prototypical follower, a highly effective 'intelligencer' in the terminology of the time.[58] He was not an original thinker, but a central node in a network of information dissemination and an effective organiser of an intellectual elite into following a coherent programme. He

[54]Grafton, *Worlds* (2009), 98–113.
[55]Bacon, *Valerius Terminus* (1734).
[56]Rossi, *Bacon* (1978), 18.
[57]Hartlib and his close friend John Dury (1596–1680), a Calvinist minister, were deeply religious Protestants who strongly felt that the spreading of knowledge in the Baconian fashion would lead to a unification of the heavily splintered Protestant Churches of his time. He was also keenly interested in agriculture, Helmontian chemistry, medicine, and was issued a large number of patents. He and his followers shared a deep belief in the potential of technical progress based on increased knowledge free of the obfuscations and confusions of the past. One of his main projects was his 'Office of Address and Correspondency', a kind of virtual Solomon's House in which useful knowledge would be circulated and distributed by means of epistolary networks, a precursor of the basic Enlightenment project to reduce access costs and enhance the dissemination of scientific and technological knowledge.
[58]The term was apparently first applied to him by John Winthrop, governor of Massachusetts. Webster, *Great Instauration* (2002), 3, sees him as the one who undertook the Baconian ideal of organizing Europe's intellectuals in a 'noble and generous fraternity' – obviously an early version of the eighteenth-century Republic of Letters. One of his main projects was his 'Office of Address and Correspondency', a kind of virtual Solomon's House in which useful knowledge would be circulated and distributed by means of epistolary networks, a precursor of the basic Enlightenment project to reduce access costs and enhance the dissemination of scientific and technological knowledge.

was an inveterate correspondent and instrumental in disseminating scientific writing in a wide array of applied fields, ranging from medicine to horticulture. He and Dury followed Bacon in the judgement of the value of knowledge in its degree of 'usefulness'. He was instrumental in disseminating scientific writing in a wide array of applied fields, ranging from medicine to horticulture.[59] Through a wide networks of correspondents and personal acquaintances, Hartlib laid the foundation of the Royal Society founded by the end of his life. It should be added that Hartlib drew his inspiration from other sources as well, such as German Calvinism, and also helped introduce the new chemistry of van Helmont and the metaphysics of Descartes into the Cambridge of the young Isaac Newton.[60] The other group of Baconians congealed at Oxford's Wadham College around John Wilkins, including such notable intellectuals as John Wallis, Christopher Wren and William Petty.[61] This was a heterogeneous group, and the new cultural beliefs proposed by Bacon were, by their very nature, syncretic and eclectic.

The so-called 'invisible colleges' that formed in England before 1660 were inspired by if not dedicated to the ideas of Francis Bacon. There was also the 'Rota Club', a debating club, founded by the radical political theorist James Harrington, which met in a coffee house for a brief period in 1659, and resembled the Royal Society in some ways.[62] These informal organisations transformed into the Royal Society in 1662, whose declared purpose it was to increase useful knowledge, and to build bridges between formal science and the actual practical applications of the 'useful arts'. Michael Hunter has summarised the purpose of the Royal Society as enhancing the standing of science in the eyes of the public, as well as providing a forum for carrying out the actual research that would augment useful knowledge.[63]

The Royal Society was in many ways the embodiment of Bacon's dreams as expressed in *New Atlantis* and *The Great Instauration*, but as Hunter points out, the timing and precise form of its establishment were contingent on the historical circumstances being aligned in 1662. Even so, most scholars would agree with Lynch that 'The Royal Society was a Baconian institution' and that it had 'a significant impact on future developments in science and a wider social impact as well [. . ., that] can be felt during the remainder of the century, throughout the eighteenth century, and beyond'.[64] At first, the Royal Society made valiant efforts to concentrate its efforts on technological matters, such as sponsoring a special committee looking in the feasibility of planting potatoes as a means of averting famine. Yet in the end, the emphasis on

[59]Hartlib was particularly interested in bee-keeping, both as an interesting agricultural pursuit and because he saw the symbolism of bees pollinating flowers in analogy to men of learning spreading information to increase the productivity of the economy.
[60]Greengrass et al., *Hartlib* (1994), 18.
[61]Wilkins was a good example of the kind of talented disciple needed by cultural entrepreneurs to disseminate their message. A practicing Puritan clergyman and widely renowned theologian and a founding father of the Royal Society, his work shows how religion and scientific endeavour complemented one another at this time. He foretold, in Charles Gillispie's words, 'with surprising insight the accommodation to be reached between Galileo's mathematization and Bacon's socialization of science'. Gillispie, *Edge of Objectivity* (1960), 113. His work on developing a universal language was directly inspired by Bacon, see Lynch, *Solomon's Child* (2001), 116–156.
[62]Hunter, *Establishing the New Science* (1989), 8.
[63]Ibid, 15.
[64]Lynch, *Solomon's Child* (2001), 233–234.

technology was toned down, perhaps because results were harder to achieve.[65] Although 'restoration science was self-consciously Baconian', Bacon's intellectual influence on the Royal Society should not be exaggerated. In the end, it was an organisation in which diverse scientists, who worked on their own, met, communicated, interacted, but then went their separate ways just as they had before.[66] Any simplistic causal line that connects the Royal Society with the Industrial Revolution would be misleading, or else the Industrial Revolution would have occurred a century earlier. However, the Royal Society was one more reflection of a cultural change that cumulated power and momentum in the late seventeenth century and the first half of the eighteenth century and its debt to Bacon is undeniable.

The great experimentalist Robert Boyle expanded the ideas of the Master, pointing out that Lord Verulam (Bacon) had made a distinction between 'luciferous' (enlightening) and 'fructiferous' (useful) experiments, but that in fact the one led to the other. 'There is scarce any physical truth which is not, as it were, teeming with profitable inventions and may not by human skill and industry and industry be made the fruitful mother of diverse things'.[67] In many ways, Boyle adapted and modified Bacon's writings. He pointed out in his *Usefulness of Experimental Philosophy* that while the Baconian distinction between the two kinds of useful knowledge was valid, the two could not be separated but strongly complemented one another. Luciferous experiments, he noted, which helped us detect the causes of things would become exceedingly fructiferous because 'man's power over the creatures consists in his knowledge of them'.[68] Michael Hunter aptly remarks that Boyle's conviction that science should produce practical inventions and lead to technological improvements may have been disappointing at the time, but his vision was prophetic.[69] We should, however, not exaggerate this motivation and suppose that materialistic motivations alone drove science in those days. Boyle, and most of his contemporaries, still believed strongly that there was inherent virtue in natural knowledge, much as classical writers such as Seneca had.

Yet virtue had to share the stage with usefulness. One example of this kind of influence that Baconian thought can be seen in the work of John Evelyn (1620–1707), mostly famous for his diary and his complaints about London's air pollution. But Evelyn was also greatly interested in horticulture and forestry, and wrote a book on trees, which was clearly indebted to and inspired by Bacon.[70] Nowhere was there so

[65]Ibid, 31, 77–78.
[66]Hunter, 'Debate' (1995), 102.
[67]Boyle, *Works* (1744), 155. Rose-Mary Sargent points out that Boyle derived from Bacon a general epistemological outline of his experimental philosophy – the sign of knowledge was no longer the deductive certainty of classical philosophy; knowledge was now that which has a 'tendency to use', see Sargent, 'Learning' (1994), 59.
[68]Boyle, *Works* (1744), 154. In essay IV in his *Some Considerations Touching the Usefulness of Experimental Natural Philosophy* entitled significantly 'That the Goods of Mankind May Be Much Increased by the Naturalist's Insights into Trade' published in 1671, he defended the proposition that the Naturalist's knowledge would enrich technology, but that his knowledge of technology would improve his naturalist science as well, Boyle, *Works* (1744), 167–176.
[69]Hunter, *Boyle* (2009), 5.
[70]Evelyn, *Sylva* (1670/1664). William Lynch insists that in this book Evelyn applied Bacon's method, and that the results do not fit the stereotypes later commentators attached to Bacon of 'undirected empiricism' but extensive and disciplined use of analogy, see Lynch, *Solomon's Child* (2001), 37.

much promise in carrying out that programme as in medicine. Robert Boyle himself devoted considerable sections of his *Usefulness of Experimental Natural Philosophy* to medicine. Thomas Sydenham, another keen follower of Bacon, was a pioneer in applying Bacon's empirical method to medical research.[71] The development of nosology was recognised for carrying out Bacon's call for physicians to collect disease histories, as part of the Baconian 'Great Instauration'.[72] But in other areas, too, data collection and experimentation were intensified: botany, zoology, metallurgy, agriculture, mining – all became legitimate areas of study. Another example of Baconian philosophy in action was presented by John Ray, one of the founders of modern zoology, for whom natural history and religion coincided. His hugely popular 1691 three-volume work, significantly entitled *The Wisdom of God Manifested in the Works of the Creation* went through 11 editions and was still reprinted in 1798.[73]

It is interesting to note that Francis Bacon's influence on seventeenth-century British intellectuals extended equally to Puritans and non-Puritans and, as Charles Webster has noted, his system of natural philosophy was framed in the context of a millennial expectation of the domination of man's dominion over nature.[74] His writings attained almost scriptural authority amongst Puritans, and 'no figure was more influential in stimulating his countrymen's active participation in experimental science and drawing the natural philosopher and the craftsman in the centre of social scene'.[75] And not just his countrymen either. Samuel Hartlib was Prussian

[71]Robert Merton notes that the growth in interest in medical science in the seventeenth century was an aspect of the growth of interest in science. For the vast majority of medical practitioners, this was probably at best only marginally the case; see Merton, *Science* (2001/1938), 24. The strong connection between biology and medicine was a product of the nineteenth century. But for the very top medical practitioners such as Sydenham, and his followers such as Richard Blackmore (1654–1729), famous for being a writer of dull poetry, and Thomas Dover (1660–1742), a physician who turned privateer, the impact of Baconian ideology is quite marked. Sydenham's impact on Continental medicine (such as on the great Dutch physician Herman Boerhaave) was also quite large; see Poynter, 'Sydenham's Influence' (1973), 223–234.

[72]Bynum, 'Nosology' (1993), 343. The systematic collection of information was extended in this age to surgery, up to then a little-respected craft. Richard Wiseman (1621–1676), the Royalist surgeon who served in the Civil War, published his *Chirurgicall Treatises* in 1676, in which he listed a catalogue of 660 individual cases. While there is no explicit mention of Bacon in Wiseman's book, he sighs in his introduction that:

> when the young chirurgeon shall find the cure easie in the Theory and appear so at first in the practice too, yet suddenly [the condition] deceive him with a Relapse [. . .] he will then wish that all other practitioners had done what I have done in this *Treatise* viz. recommend their observations both successful and unsuccessful, thereby increasing Knowledge in our Profession, and leaving Sea-marks for the discovery of such Rocks as they themselves have split upon before. [Wiseman, *Treatises* (1719), v–vi]

[73]Seventeenth century writers on farming and natural history explicitly acknowledged their debt to Francis Bacon and especially his *Sylva Sylvarum*, a somewhat indiscriminate collection of facts and putative facts, which included the *New Atlantis* as an appendix. Between 1626 and 1685 this work became something of a best-seller, with sixteen English and three Latin editions; see Gaukroger, *Emergence* (2006), 33.

[74]Webster, *Great Instauration* (2002), 27, 335.

[75]Ibid, 335.

(even if he lived most of his life in England) and Jan Amos Comenius was Czech.[76] Almost a century after their deaths (in 1662 and 1670, respectively), Denis Diderot's life work was still explicitly inspired by Bacon's work, and his *Encyclopedia* was permeated with Baconianism.[77] Progress was to be secured, he felt, if and when artisans understood the principles underlying their techniques and knew the reasons why they worked. Bacon's influence on the French Enlightenment was pervasive even if their knowledge of the contents of his work was at best superficial.[78]

It was not only the liberalism and political critique that accounted for the popularity of Diderot's *Encyclopedia.* As Gillispie noted, 'it was the technology, taking seriously the way people made things and got their livings, dignifying common pursuits by the attention of science'.[79] It is exactly on that topic that Bacon's role as a cultural entrepreneur can be discerned. His most powerful impact was, indeed on the Enlightenment, which admired him as a propagandist of natural inquiry that held the key to social progress. Bacon's basic philosophy could be regarded as what later came to be seen as 'Whiggish', and it is not surprising that the arch Whig historian Lord Macaulay, in his long essay on Bacon (1837) hailed his

[76]The earliest admirers of Bacon were indeed on the European Continent, among them René Descartes who in one letter expressed the view that he and Lord Verulam (Bacon) complemented one another. Two other leading French intellectuals of the era, Pierre Gassendi and Marin Mersenne, were influenced by his work. So was the Dutch philosopher and physicist Isaac Beeckman. Yet while many of these writers agreed with some of the central tenets of Bacon's method, they often misconstrued his work and did not share the aggressive approach towards the exploitation of nature and drive towards technological progress, much less the inductive methodology; see Pérez-Ramos, 'Bacon's Legacy' (1996), 312.

[77]d'Alembert, *Preliminary Discourse* (1995), 74–75 refers to Bacon as:

> the immortal Chancellor [. . .] the greatest, the most universal, and the most eloquent of the philosophers [. . ., who] conceives of philosophy as being only that part of our knowledge which should contribute to making us better or happier [. . .] confining it [. . .] to the science of useful things.

Voltaire, in his *Philosophical Letters* called him 'the father of experimental philosophy' and added that the *Novum Organum* was the scaffold by means of which the edifice of the new philosophy has been reared; so that when the building was completed, the scaffold was no longer of any use. Chancellor Bacon was still unacquainted with nature, but he perfectly knew, and pointed out extraordinarily well, all the paths which lead to her recesses'' [Voltaire, 'Philosophical Letters' (1901), 47]. Even the curmudgeonly Rousseau, who had little sympathy for philosophies of technological progress, admitted that 'Verulam was perhaps the greatest of philosophers'. See Gauss, *Rousseau* (1920), 58–59.

[78]Voltaire, 'Philosophical Letters' (1901), letter XII. Michel Malherbe points out that despite their admiration for him, most of the French *philosophes* had actually read little of his work, and that even the article on *Baconisme* in the *Encyclopédie*, written by the Abbé Pestré, shows little evidence of having read much of Bacon's work; see Malherbe, 'Bacon' (1985), 387–404.

[79]Gillispie, *Edge of Objectivity* (1960), 174. Bacon's influence on Robert Hooke, after Newton the most ingenious and talented English scientist of his age, can be seen from Hooke's somewhat exaggerated plan to write the history of every artisanal occupation, including the makes of counterfeit pearl and precious stones, bugle-makers, book-binders, dancing masters, varnishers and so on; see Farrington, *Bacon* (1979), 137.

work as prophetic.[80] On the other hand, idealist German philosophers were, naturally, less impressed.[81]

Today, to be sure, much of Bacon's legacy on the History of Science can be disputed, but his impact on the prestige and agenda of scientific endeavours and indeed on all studies of useful knowledge, including technology, is undiminished. The consensus view is still that 'the ethos he infused into modern science as something inherently related to social development remains [...] part of our categorical framework'.[82] In other words, Bacon's heritage is nothing less than the cultural acceptance of the growth of useful knowledge as the critical ingredient of economic growth.

4. Isaac Newton as a cultural entrepreneur

Newton's career, like that of many important entrepreneurs, was an illustration of unintended consequences. Margaret Jacob, the foremost proponent of the central role of a 'Newtonian Enlightenment' in the rise of industrial society has argued that Newtonianism was key to subsequent technological development, but in fact it is not easy to show how Newton's science *directly* led to any specific inventions.[83] The distinction made by Jacob between Newton's work and what became known as Newtonianism is key here. Newton was no real forerunner of the Industrial Revolution. He was more interested in motion than in heat, and yet it is the latter that turned to be crucial to most developments in power and materials. Mechanical science, as developed by Galileo and Newton, was initially of little direct help to the mechanical advances in the textile industry. Differential calculus, Newton's most practical invention, did become useful to some engineers in the second half of the

[80]Macaulay noted that:

> some people may think the object of Baconian philosophy [to provide a man with what he requires to continue to be a man – that is technology] a low object, but they cannot deny that, high or low, it has been attained [...] they cannot deny that mankind have made and are making great and constant progress in the road which he pointed out to them. [Macaulay, 'Lord Bacon' (1837), 129–132]

Triumphalist these lines are without a doubt, but by the time they were published, on the eve of the Victorian era, they were based on real and palpable technological achievements in the British Industrial Revolution.

[81]Thus Hegel writes somewhat acerbically that:

> Since Bacon has ever been esteemed as the man who directed knowledge to its true source, to experience, he is, in fact, the special leader and representative of what is in England called Philosophy, and beyond which the English have not yet advanced. For they appear to constitute that people in Europe which, limited to the understanding of actuality, is destined, like the class of shopkeepers and workmen in the State, to live always immersed in matter, and to have actuality but not reason as object [...]. His practical writings are specially interesting; but we do not find the bright flashes of genius that we expected. As during his career in the state he acted in accordance with practical utility, he now, at its conclusion, likewise applied himself in a practical way to scientific endeavours. See Hegel, *Lectures* (1805/1806).

[82]Pérez-Ramos, 'Bacon's Legacy' (1996), 311.

[83]The most recent and eloquent statement of her position is in Jacob/Stewart, *Practical Matter* (2004), 26–60.

eighteenth century, but it is not easy to assess its exact role in technological progress.[84]

If Newton had a role to play in the Industrial Revolution, it was through his impact as a cultural entrepreneur, that is, through changing other people's beliefs and attitudes. He was an unlikely candidate for that position, as Keynes pointed out in his posthumous lecture on 'Newton, the Man'.[85] Indeed, he may well have become a cultural entrepreneur despite himself: his aim in writing, Robert Iliffe has noted, was to deal only with a tiny select band of the mathematically sophisticated. By his own admission, he made the *Principia* abstruse, so as to be understood only by 'able mathematicians' who would 'concurr with him in his Theory'.[86]

What was it, then, that Newton contributed to the changing culture that ended up having such profound economic consequences? In part it must have been that his career and the enormous admiration he garnered in his lifetime and beyond served as a model and example for others. He was knighted, elected to Parliament and became quite wealthy. He was surrounded by admiring students (most notably Richard Bentley, Samuel Clarke and William Whiston), and was on close terms with all the leading intellectuals and scientists of his age, unless he had quarrelled with them.[87] The only other intellectual of the age whose stature in modern assessment resembles Newton's despite differing from him in his search for indisputable 'facts', John Locke, noted his achievement.[88] His patronage job as master of the mint, and the many attractive offers he declined amply demonstrate

[84]The first and best-known application of calculus was to hydraulics, but the French mathematician Antoine Parent famously erred in his computation of the maximum useful effect that a waterwheel could draw from the force of a stream.

[85]Keynes noted that:

> For in vulgar modern terms Newton was profoundly neurotic of a not unfamiliar type, but – I should say from the records – a most extreme example. His deepest instincts were occult, esoteric, semantic-with profound shrinking from the world, a paralyzing fear of exposing his thoughts, his beliefs, his discoveries in all nakedness to the inspection and criticism of the world. "Of the most fearful, cautious and suspicious temper that I ever knew", said Whiston, his successor in the Lucasian Chair. The too well-known conflicts and ignoble quarrels with Hooke, Flamsteed, Leibniz are only too clear an evidence of this [. . .]. He parted with and published nothing except under the extreme pressure of friends. Until the second phase of his life, he was a wrapt, consecrated solitary, pursuing his studies by intense introspection with a mental endurance perhaps never equalled. See Keynes, 'Newton' (1946).

[86]Iliffe, 'Is He like Other Men?' (1995), 175.

[87]One of his most dedicated disciples was the Scottish mathematician John Keill (1671–1721), who taught at Oxford as the Savilian Professor of astronomy and who vigorously defended Newton in his priority dispute with Leibniz. Keill's student, John Theophile Desaguliers, became the leading exponent of Newtonian mechanics in Britain (see below). Another acolyte was the Swiss mathematician Fatio de Duillier (1664–1753), who was particularly instrumental in communicating Newton's view to leading Continental scientists such as Christiaan Huygens.

[88]'Yet the incomparable Mr. Newton has shown how far mathematics, applied to some part of nature, may, upon principles that matters of fact justify, carry us in the knowledge of some [. . .] particular provinces of the incomprehensible universe'. Locke, 'Thoughts' (1812/1693), 186.

his celebrity and prestige.[89] No wonder that his life provided a model that others were hoping to follow, much like Watt's career did for engineers a century later.[90] The effective allocation of talent and human capital in the extreme right tail of the distribution of creative talent is highly sensitive to such signals.

Newton thus continued what Galileo and the Puritans had started: to raise the social standing of scientists and researchers as people who should be respected and supported and to provide them with a comfortable material existence. The respectability of research that augments useful knowledge was embodied in the Royal Society that he presided over. The implied message was that the work of natural philosophers was destined to become the primum mobile of social progress by carrying out Bacon's call for intelligibility, and Newton had shown once and for all that this was feasible. Thus, Newton also contributed enormously to the rise of the status of *science* as a valuable human activity contributing to the well-being of mankind, worthy of the patronage and support of wealthy people.[91] Hans Sloane, Newton's successor as President of the Royal Society, basked in the prestige of his predecessor to elevate the prominence of natural history. With all this fame came, of course, no small measure of personality cult throughout Europe.[92]

In terms of his impact on his intellectual environment, there can be no question that Newton's work was the last nail in the coffin of the 'ancients' in their struggle with the 'moderns' on the question whether modern culture could measure up to the achievements of classical civilisation.[93] Precisely because Newton's work amounted, in the eyes of contemporaries to 'a hundred times more than what all the ancient Philosophers knew together', the idea that useful knowledge was on an upward trend became deeper and deeper ensconced in the minds of intelligent contemporaries.[94] As such, many other branches of knowledge tried to develop elegant models much like Newton's model of celestial mechanics and followed the lead of his mind. The tangible results were at first mixed at best. Newton's excursions in chemistry in the famous 'query 31' at the very end of the third edition of his *Optics*, for instance, included a discourse about chemical affinity that later inspired other chemists, such as Etienne François Geoffroy (1672–1731), to compile the first tables of chemical

[89]Among others, the visiting French scholar Jacques Cassini offered him in 1698 a large pension by Louis XIV that would have involved an appointment at the Royal Academy of Sciences, as well as the mastership of Trinity College; Westfall, *Never at Rest* (1980), 587–89. Although little interested in acquiring wealth, he left his nieces and nephews a liquid estate of £ 32,000 in 1727 (id., 870).

[90]MacLeod, *Heroes* (2007).

[91]As Michael Hunter has pointed out, the prestige of the scientific endeavour and culture was by no means assured in Restoration England. Only after 1700, he notes, 'under the presiding genius of Newton, science became increasingly orthodox, systematic, and influential'. Hunter, 'Debate' (1995), 119.

[92]Thus, for example, the prodigiously gifted Italian scholar Cesare Beccaria (1738–1794) was dubbed 'Il Newtoncino' by his admirers; see Gay, *Enlightenment: An Interpretation* (1966), 12.

[93]For summaries of this debate, which seems so absurd to us today, see especially Jones, *Ancients and Moderns* (1961), Spadafora, *Idea* (1980). Oddly enough, Newton himself seems to have believed that much of what he had discovered was already known by the ancients Greeks but had been lost subsequently; Iliffe, 'Is He like Other Men?' (1995), 165–168.

[94]Cited by Spadafora, *Idea* (1980), 48.

affinities.[95] In the same query, Newton conjectured that his scientific method may even be able to 'enlarge the bounds of moral philosophy' (Newton, 1719, p. 381). The Dutch physician Herman Boerhaave (1668–1738), who taught medicine, chemistry and botany at Leiden between 1709 and 1738 ascribed to Newtonian principles the key to explain the human body in terms of gravitation and attraction.[96] Even some of the work of the ever-sceptical David Hume, especially his 'science of man', has been argued to be modelled in part on Newton's successes in natural philosophy, and Hume certainly appears to want, in places, his readers to feel that he is modelling his project on the successes of natural philosophy exemplified by Newton suggesting that his 'science of man' can parallel recent achievements in natural philosophy.[97] Newton's impact on economics, especially Adam Smith, has also recently been emphasised.[98]

Newton's other contribution was the sanctification of the use of mathematics in the generation of useful knowledge. Continental Europe had long accepted this: Galileo, Descartes, Torricelli, Huygens and Leibniz all used mathematics in their natural philosophy. In England, this insight arrived late and Bacon had no interest in mathematics as a tool of research.[99] Nor, it seems, did many of the British scientists between Bacon and Newton. Robert Boyle, for instance, argued against the use of mathematics in experimental science and his own mathematical aptitude is in dispute.[100] Newton combined the deductive powers of mathematical modelling with Baconian induction, showing that the two were not only capable of coexisting in the same mind but were actually complementary. Newton's stature was continent-wide. His influence on how useful knowledge was collected, analysed and distributed was consequently both wide and deep.

Newton's impact on the physical sciences was, a fortiori, enormous. His insights more than ever confirmed the beliefs of a mechanistic, understandable universe that

[95]Brock, *History of Chemistry* (1992), 76.

[96]Dobbs/Jacob, *Newton* (1995). Boerhaave serves as another classic example of the kind of epigone that is instrumental in disseminating the ideas of the true cultural entrepreneurs, in his case Descartes and Newton. Famous and celebrated in his own days, his original contributions were few and middling, yet he helped spread the main cultural beliefs of the Enlightenment, not only in his own country but throughout Europe.

[97]Schliesser, 'Hume's Newtonianism' (2007).

[98]In his *History of Astronomy,* Smith wrote that:

> Such is the system of Sir Isaac Newton, a system whose parts are all more strictly connected together, than those of any other philosophical hypothesis .... His principles, it must be acknowledged, have a degree of firmness and solidity that we should in vain look for in any other system. The most sceptical cannot avoid feeling this .... Can we wonder then, that it should have gained the general and complete approbation of mankind, and that it should now be considered, not as an attempt to connect in the imagination the phenomena of the Heavens, but as the greatest discovery that ever was made by man, the discovery of an immense chain of the most important and sublime truths, all closely connected together, by one capital fact, of the reality of which we have daily experience. For a recent analysis see Montes, 'Newton's real influence' (2008).

[99]Gaukroger, *Bacon* (2001), 20–7.

[100]Shapin, 'Boyle' (1988). There were exceptions, of course, such as the mathematician John Dee, who is believed by some to have been more advanced in his thinking than Bacon. This case has been heavily contested. In any event, while his introduction to Euclid's works remained quite influential, it is quite clear that his subsequent influence was far more limited than that of Bacon.

could and should be manipulated for the material benefit of mankind. Some notion of the creation as a clockwork mechanism had been around since the middle ages, but what counted was its triumph over what their proponents regarded as obscurantism and superstition. Seventeenth-century science prepared the ground for the Industrial Enlightenment by stressing mankind's relationship with the environment as based on intelligibility and instrumentality.[101] Instrumentality basically meant that at some level what people at the time called 'hypothesis', that is, the metaphysical causes of the 'essence' of a phenomenon (or, in the language of economics, the micro-foundations) mattered less than it modus operandi and how it could be harnessed. This is, of course, precisely what Newton did. He did not claim to understand *why* the principles he discovered were there, only that they were universal and could be understood by generally applicable principles. The implication was that once nature was intelligible, it could be manipulated, controlled and applied to human needs as Bacon had advocated.

Intelligibility, above all, depended on a mechanistic view of the world. The concept of a mechanical universe in which the regularities were wholly predictable and deterministic, although in the air for a long time, was given an enormous boost by Newton's work. These trends were the products of the thought and labours of many people, some famous, some obscure. But there is no question that Newton's work persuaded a large number of educated and informed people that a project of material improvement, in the Baconian tradition, based on a mechanistic view of the universe was feasible. Carrying it out, of course, turned out to be a huge undertaking, especially because so many relevant areas such as medicine and agriculture turned out to be more complex than anyone had imagined.

Newton's combination of his formidable mathematical and analytical skills with his continuous reliance on empirical and experimental data was regarded in his own day as a shining example that lesser scientists could only hope to mimic. The classical canon had been largely based on logic and authority; Bacon had wanted to replace it altogether with facts and data that, somehow, would then fall into place. In the end one should always prefer principles gained by induction from observation.[102] Anyone who believed in the feasibility and desirability of progress must have found this message congenial.

Yet, as I noted above, the apostles and epigones of every cultural entrepreneur adapt and alter the original message, and Newton was no exception. Newton was not a Newtonian.[103] He showed little taste in his lifetime for applications, and, unlike his nemesis Robert Hooke, invented little worth mentioning. Most of his immediate followers and epigones, too, were not famous for large technological advances. It is hence unwarranted to draw direct links of anything we may call 'Newtonianism' and the sudden acceleration of the rate of technological innovation after 1760.[104] The

[101]Dear, *Nature* (2006).
[102]Iliffe, 'Philosophy' (2003), 272.
[103]Dobbs/Jacob, *Newton* (1995), 61.
[104]Jacob, *Scientific Culture* (1997) has expressed this view most eloquently. It is true that the career and work of Jean T. Desaguliers exemplifies the positive effect of Newtonianism in Britain, focusing on the practical and useful application of the new mechanical science, but during Desaguliers's life (1683–1744), nor that of other similarly minded Newtonians of that age such as James Jurin (1684–1750), no Industrial Revolution took place.

connection between the Scientific Revolution and the Industrial Revolution was more subtle.

It is true that some of Newton's followers were able to demonstrate his principles using mechanical devices. But, as the late Donald Cardwell and others have noted, the dispute between the Newton measure of force (momentum, or mass times velocity) and the Huygens–Leibniz notion of vis viva (momentum times velocity squared) was not altogether in Newton's favour, as the vis viva concept was more useful to engineers interested in 'work', duty and efficiency.[105] The confusing dispute regarding which of the two concepts was to be preferred illustrates the fact that Newton's work left a lot for the future and that concepts such as momentum, force, work, power and torque had not been fully worked out until late in the eighteenth century.[106]

Perhaps the most important contribution that Newton's work made to the Industrial Enlightenment was the elegance and completeness with which he explained observed phenomena and regularities that had puzzled people for centuries. The point was not just that his equations, which explained celestial motions as well as provided a theoretical basis for much that had been known before on the motions of earthly bodies and the behaviour of light, provided a world of order and logic. The real advance was that the Baconian ideal of understanding nature through observation and experiment and thus its control seemed suddenly so much closer after 1687. As Feingold has phrased it eloquently, 'by becoming science personified [...] Newtonian Science also became the model to emulate, the manifestation of "superior knowledge" that summoned all other learning to reorient itself along similar lines'.[107] Newton's work filled other scholars with hope that areas such as farming, medicine, chemistry, electricity, materials and even the 'science of man' would soon be similarly reduced to well-understood elegant laws. The cultural importance of Newtonianism was not so much in its discoveries as such as much as what it implied for the 'most fundamental of human problems – that is to say, the relation of man to nature and of both to God'.[108] It is this relation which is the cultural change on which much of the exponential growth of useful knowledge relied, and the economic consequences thereof cannot be understood without it.

The impact of Newton on the thin but strategically placed class of European intellectuals in the eighteenth century was immense and famously summarised by Alexander Pope's well-known line ('God said, let Newton be! And all was light'). A whole industry of books interpreting and explaining Newton sprung up, often written in languages other than English and then translated further. Of those, the one by Voltaire (*Élements de la Philosophie de Newton*) was translated back into English, as was that of the leading Dutch Newtonian, Willem s'Gravesande (1688–1742).[109] In Germany, the leading Newtonian was the mathematician Jakob Hermann who

[105]Cardwell, *Turning Points* (1972), 49–50.
[106]Home, 'Physics' (2003), 361.
[107]Feingold, *Newtonian Moment* (2004), 148.
[108]Becker, *Heavenly City* (1932), 61–62.
[109]See Voltaire, *Élements* (1738); s'Gravesande, *Elements* (1720), translated into English (from Latin) by none other than Jean T. Desaguliers himself. A sixth edition of s'Gravesande's book was published in 1747, and the influence of this book is attested by its impact on the intellectual development of Joseph Priestley, a central figure of the English Industrial Enlightenment; Schofield, *Enlightenment* (1997), 24–28.

taught for years in Padua and in St Petersburg, and who published a book on mechanics named *Phoronomia*. In Italy, the impact of Newton can be measured by the appearance in 1737 of *Il Newtonianismo per le Dame* (Newtonianism for Ladies) by Francesco Algarotti.[110] Over time, Newton's standing only rose.[111]

Like so many entrepreneurs, Newton succeeded in some dimensions and failed in others. His success in persuading contemporaries and posterity of the correctness of his physics did not extend to his metaphysics. There is a deep irony in this that is hard to miss.[112] Newton was a deeply religious man, for whom his findings affirmed the ever-presence of a wise deity who had created a world of knowable regularities.[113] But Newtonian mechanical philosophy did not strictly require a personal God, and it is telling that many of his Enlightenment followers, above all Voltaire, could uncouple his scientific works from his faith and adopt the former without paying much attention to the latter.[114] Enlightenment science often coexisted with religion, but it needed it less than the Puritan scientists did in the mid-seventeenth century. Newton also believed fervently in alchemy, not as an eccentric hobby but as a central part of his intellect, hoping that he could learn from it about the supernatural world, about 'the operations of a deity in organizing and vivifying the inert particles of matter in the microcosm'.[115] Yet alchemy (in its narrow sense) was a dead end, and the eighteenth century turned away from it.

Whether Newton would have approved of the way his reputation and methods were used in the eighteenth century or not, his impact on the cultural and technological elite of eighteenth-century Europe was inestimable. For Enlightenment intellectuals, they created a simple and linear historical tale of a road to the truth, in which many dead ends were avoided, from alchemy to Descartes's vortices, but Newton represented all that was true. Already during his lifetime, a personality cult emerged.[116] Peter Gay points out that 'in the deification of Newton, the Enlightenment of the *philosophes*

[110]Algarotti's book became a huge best-seller: it was translated into French in 1738 and English in 1739 and into many other European languages; Algarotti, *Newton's Philosophy* (1739). See also Mazzotti, 'Newton' (2004).

[111]In a famous anecdote, the French mathematician Jean-Baptiste Delambre's in his eulogy of the great mathematician Lagrange recounts that Lagrange often cited Newton as the greatest genius that ever existed but also the luckiest, because there was only one universe the laws of which he could discover; Delambre, 'Notice' (1867), xx.

[112]Dobbs goes as far as dubbing Newton as one of 'history's great losers', failing in his aim to stem 'the tides of mechanism, materialism, deism and atheism'. Dobbs, 'Newton' (2000), 38–39.

[113]While it is perhaps far-fetched to see in his Arianist (and thus heretical) convictions a driving force for his science, his Christian faith affirmed and supported his scientific work. He could do this by developing eclectic and idiosyncratic religious beliefs that were designed to be consistent with his scientific insights. He ignored the problems that his mechanical theory posed for cosmogenesis and ostensibly adhering to the literal biblical text. See Snobelen, 'Newton' (1999).

[114]Voltaire regarded Newton practically in religious terms, regarding himself as Newton's apostle and admitted that Newton was the 'God to whom I sacrifice', Feingold, *Newtonian Moment* (2004), 104.

[115]Dobbs, 'Newton' (2000), 37–38.

[116]A telling example is a 1797 letter from the eminent Scottish scientist John Robison to his friend and protegé James Watt, in which he begs Watt to present him with some original letters written by Isaac Newton, explaining it by his 'superstitious veneration for every relick of that wonderful man. I would given anything to have Scrap, however insignificant, of his writings'. Robinson/McKie, *Partners* (1970), 272.

and the age of Enlightenment were at one'.[117] Deification, of course, has been an inevitable side effect of successful cultural entrepreneurship from Jesus to Marx, and Newton did not escape. He received far more hero worship in the age of Enlightenment than modern historians of science are comfortable with. Margaret Jacob, who notes this feature, points to one of the key figures of the intersection of science and the Industrial Revolution, the chemist John Dalton, who believed that British industrial success depended on its understanding of Newtonian mechanics, and that the only contemporary who was ranked with Newton was, interestingly enough, the engineer John Smeaton.[118] The myth created around the time of the Industrial Revolution about the relentless advance of knowledge has been replaced in our time by a more nuanced and textured narrative, and a few have even thrown away the baby of economic progress with the bathwater of triumphalism. Regardless, the power of this myth in motivating the men who made the Industrial Revolution and in coordinating their beliefs on a set of propositions was a part of the machinery of technological progress. In that coordination process, the work and personality of Newton served as a focal point, and it is exactly there that his function of cultural entrepreneur assumes its true significance.

5. Concluding remarks

Despite the huge literature that uses the term 'culture' in one form or another form in historical explanation, we actually know fairly little about why some ideas and beliefs win out in the competitive marketplace for ideas. By far the most persuasive and rigorous literature on this topic comes not from 'cultural studies' but from cultural evolution.[119] Oddly, economic historians have taken little interest in this literature, with the exception of (some) historians of technology.[120] The insights that evolutionary theory lends to this issue are explored at length elsewhere, but can be briefly summarised here.[121] The idea is basically that cultural beliefs and attitudes are passed on from generation to generation through vertical (parent and child), horizontal (peers and media) or oblique (teachers and similar sources) transmission channels. Cultural change will be faster the more socialisation is determined by sources other than one's parents. This allows people to make choices, and thus the process might be termed choice-based cultural evolution.

The speed and power of this process depends to a large extent on the technology of information transmission. It is, therefore, no accident that the years after 1,500 saw more cases of successful cultural entrepreneurship. The printing press improved communications and transportation, and the emergence of a transnational intellectual community all helped create opportunities for original and brilliant intellectuals to influence culture. Unless one wishes to brush aside altogether the role of

[117]Gay, *Enlightenment: The Science of Freedom* (1969), 130. Gay, *Enlightenment: The Science of Freedom* (1969), 133, that the many poetic tributes to Newton (of which Alexander Pope's famous lines are only the best-known example), while mechanical and monotonous, were fervent and sincere and were a reflection of 'a new attitude toward nature, toward knowledge, toward the world'.
[118]Jacob, 'Truth' (2000), 320.
[119]For a recent survey, see Mesoudi, *Evolution* (2011).
[120]Ziman, *Technological Innovation* (2000). Mokyr, 'Useful Knowledge' (2006).
[121]Mokyr, *Cultural Origins* (in preparation).

entrepreneurs and entrepreneurship in economic history, their role in focusing and coordinating cultural beliefs as a factor in economic change must remain on the agenda of economic history. This is not to say that Bacon, Newton and the other great minds of the Scientific Revolution can be credited with the Industrial Revolution. Such a conclusion would be hopelessly oversimplified. The practical applications of seventeenth-century scientific culture were anything but obvious or immediate. While the matter continues to be debated, direct links between the Industrial Revolution and the conceptual breakthroughs of the previous century are not easy to find. All the same, progress was increasingly made by scientifically trained people, who believed in the experimental method, the careful collection and organisation of data, the use of mathematics and the sharing of findings and insights. The research agenda was set by people who believed that progress was the name of the game and that it eventually would be brought about by the institutions and methods of useful knowledge.

How crucial were cultural entrepreneurs in the early modern age for the subsequent economic development of Europe? To repeat, the purpose of this essay is not to hang the Industrial Revolution or modern economic growth on one or even a few individual agents. At the same time, however, we should not be tempted by the materialist position that impersonal deep forces render the actions and influence of specific individuals uninteresting because individuals were basically powerless to affect the state of affairs and that for every influential person there was a large supply of close substitutes who could have done the same. To be sure, when a gap between conventional wisdom and new facts and insights that come to light grows, beliefs are more likely to be adjusted. In science, such a gap is often due to better tools to observe nature.[122] When this gap becomes large enough we should expect opportunities for cultural entrepreneurs. But there is nothing inexorable about such adjustments. The adjustment could come on many margins, including of course suppressing the new information as being inconsistent with some canon and thus heretical.

Even if many persons are searching for new insights of one kind or another kind, the role of the cultural entrepreneur is to coordinate such beliefs and fuse them into a coherent doctrine that others can share and develop and in this way make change effective. In their different ways, Bacon and Newton did exactly that: Bacon in showing what science *should* do, and Newton in what it *could* do. I have illustrated above the enormous influence they had on following generations, especially in the Age of Enlightenment, in which the technological gap between Europe and the rest of world became decisive. Their most palpable impact was on exactly that very segment of European society which made this technological gap a reality.

My purpose has not been to 'explain' the success of the Scientific Revolution and its putative effect on the Industrial Revolution. After all, Bacon's contributions to science itself were modest at best, and Newton's work had few immediate technological applications. Instead, the way they affected economic history was through rewriting the agenda of research, the demonstration of the crucial importance of opened and shared knowledge, and the underlining of research into

[122]It may not be an accident that Bacon and Newton are spanning a period that witnessed the emergence of the telescope, microscope, thermometer, barometer, pendulum clock and air pump, as well as the astronomical observations of systematic astronomers.

useful knowledge as a respectable and virtuous activity suitable for God-fearing and loyal gentlemen.

Technological progress does not take place in a cultural vacuum. Inventors must believe, however subconsciously, in the fundamental possibility of progress and improvement and be trained to be sceptical of conventional wisdom. In those ways, they created a new scientific culture. As Margaret Jacob and others have argued, it was *scientific culture* rather than *science* itself that helped create the conditions suitable to a new world in which the growth and diffusion of useful knowledge became the main engine driving the economy forward. Moreover, cultural beliefs must support institutions that make invention and improvement attractive and profitable and provide the means to access and exchange the useful knowledge that underlies technological progress.

Like all cases of great entrepreneurs (or inventors), the counterfactual is always whether history would have been radically different without them. The answer depends on what one means by 'radically' – surely there would have been an Industrial Revolution without Bacon, Newton or for that matter Arkwright and Watt. Indeed, there would have been an Industrial Revolution in Europe even if Britain had been occupied by a reactionary power that suppressed all creativity. But it would have been different, perhaps later, slower, and in a different location. History is neither fluke nor necessity, but somewhere in between. Individuals mattered, even if they were not *all* that mattered. It is useful to study the impact of highly influential persons in relation with the environment in which they operated, and to show how and why they changed the beliefs and thus the behaviour of others.

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