

# The Industrial Revolution and a Newtonian Culture

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MIEKE MOLTHOF, AUG 24 2011

The Industrial Revolution has been one of the most remarkable events in human history, and in the long term its impact on economic development throughout the world has proven to be fundamental (Christian, 2004). In his book entitled 'the Wealth and Poverty of Nations', Landes argued: 'If we learn anything from the history of economic development it is that culture makes all the difference' (cited in Mokyr, 1999, p. 1243). But while Landes mainly focused on nations' particular ethic of work, an examination of culture with regard to economic development might also include attitudes toward the natural environment, the learning and adopting of new techniques from foreign societies, and the assuming of a mechanistic world-view that encourages to manipulate production (Mokyr, 1999). It is the meaning of culture expressed in the form of a mechanistic cosmology and the drive to mechanize the processes of production to which the following discussion and analysis will turn. In this paper, it is argued that a Newtonian culture, as the manifestation of a mechanistic world-view throughout society, facilitated the development of technological innovation necessary for the Industrial Revolution to take place (Goldstone, 2000).

The industrialization in Britain that took off in the eighteenth century was not only rooted in its commercial culture, but was also supported by the successful spread of Newtonian science through various layers in society. The spread of the new approach to knowledge and technological development to those most closely connected to the production process has with little doubt been important for the new scientific methods to be of true significance for the Industrial Revolution (Goldstone, 2000). Throughout the eighteenth century, the effects of the first wave of industrialization remained largely confined to British society (Christian, 2004). During the turn to the nineteenth century, many countries in the rest of Europe began to industrialize as well, while other great civilizations failed in this respect to keep pace (Nielsen, 2010). Recognizing the role of a Newtonian culture can contribute to a better understanding of why the Industrial Revolution took off in Britain, and why this country, and later the whole of Western Europe, left the arguably equally successful societies in China and the Islamic region behind (Findlay, 1992).

First, Newton's work and its relevance to science in the period immediately predating the First Industrial Revolution is briefly discussed. Second, an analysis is made of the significance of a Newtonian culture to the British Industrial Revolution. Third, the scientific attitude that was prevalent at the time of Western Europe's industrialization in the great civilizations of China and Islam is investigated with the aim of getting a clearer understanding of why they lagged behind.

### Newtonian science

In the Industrial Revolution rates of technological innovation had reached an unprecedented level (Christian, 2004). The Industrial Revolution was characterized by the growing significance of technology as a driving force for economic growth, and in the absence of technology the process would ultimately fail. The branch of early modern science that was in this period of special importance for technology and industrial success was the study of mechanics. This particular way of studying science has generally been associated with the work of Isaac Newton (Mokyr, 2008). During the Scientific Revolution the world-view of Newtonian mechanics was developed as the prime focus in the methodology of modern science (Mokyr, 2000a). Newtonian science seems thus to have played a most important role in the Scientific Revolution and the consequent change in cosmology that was held in many Western societies at the time. Although many scholars had questioned the assumptions of classical wisdom, Newton's approach fundamentally undermined the classical world-view of the West. In the late seventeenth century, Newton

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provided proof that motions in the universe and motions on earth could be explained by exact same principles. This made Newtonian science a cosmology completely different from others (Goldstone, 2000). Newton's ideas were published in a book entitled 'Principia', in which he provides an explanation of how the universal laws of gravitation are equally applicable to motions in heaven and motions on earth (Jacob & Stewart, 2004). Newton's complete rejection of a distinction in the laws governing motions in heaven and on earth set his view on the world apart from the ones held by equally famous scholars like Copernicus, Kepler, and Galileo. The Newtonian cosmology of a mechanical universe promoted a drive to mechanize human activities at large scale, a drive which underlaid the development of new machinery and the capacity to industrialize. The stance adopted by Newton thus considerably influenced the development of technological innovations that contributed to the Industrial Revolution (Goldstone, 2000). Bekar and Lipsey (2004) therefore state: '(I)t does not seem an overstatement to say that Newtonian mechanics provided the intellectual base for the First Industrial Revolution, which was almost wholly mechanical' (p. 24). It was perhaps not so much Newton's work that directly sparked a range of new inventions, but rather the wide public that put into practice his ideas. As Jacob and Stewart (2004) state: 'The Principia will always remain a great book, possibly the greatest ever published in science. But it was the practitioners, the audience, the new public, the buyers and consumers of the new science, who made it the cornerstone of Western economic development' (p. 15).

## Newtonian culture and the British Industrial Revolution

In scientific associations and in other educational institutions that had developed in Britain, mechanistic science was taught and discussed among scientists, engineers and entrepreneurs, and the ways in which this knowledge could be useful for production were explored (Goldstone, 2001). Science contributed to the development of the intellectual principles which underlaid the Industrial Revolution by providing the theories upon which technological creativity was ultimately based (Mokyr, 2000b). In the absence of Newtonian science, the synergy between knowledge and technology would have been far less intense and the technological advances that are of decisive importance to long-term economic growth would have been slowed down (Bekar & Lipsey, 2004). It was the spread of mechanical science to a wider public, in specific to those in close contact with the production process, that allowed for a Newtonian culture to emerge and which promoted the industrial take off. As Mokyr (2008) argues, 'in the final analysis the Industrial Revolution rested on key technological breakthroughs and their application to production by a class of successful industrial entrepreneurs' (p. 3).

Britain was the first country in which a particular culture based on Newtonian mechanics was to emerge. It was the only place where the approach was widely disseminated and applied during the entire eighteenth century (Chai, 2005). Bekar and Lipsey (2004) argue that the fact that Britain was ahead on the rest of the world in this respect guaranteed that, if the Industrial Revolution was to take off in the eighteenth century, Britain was the only place where it could. As Goldstone (2000) states, 'although France had Descartes, and the Netherlands had Huygens and relative freedom for writers, neither moved in the direction of England – to a Church-endorsed and widely preached anti-classical Newtonian mechanical world view, with practical instruction for craftsmen and businessmen in the tools of the new science' (p. 184). The upheavals in many seventeenth century societies were characterized by a state of great disturbance and disorder, and the response to these upheavals took the form of restoring stability, providing for unity, and stressing orthodoxy along the principles of classical theory (Goldstone, 2001). Only in the Protestant regions of Europe were classical assumptions fundamentally challenged.

Significantly, it was only in Britain, for at least several decades ahead of the other European countries, where a Newtonian culture, taking the form of a mechanistic view on the world, a confidence in universal laws of nature, and man's ability to manipulate the world by applying these laws, gained true ground. The extent to which the Newtonian science spread throughout British society and was put into practice by entrepreneurs distinguished Britain from every other country in Europe (Bekar & Lipsey, 2004). Through the spread of these beliefs and hence the transformation of scientific attitude and the emergence of a new culture, the accumulation of technological knowledge was facilitated and finally a point was attained at which this knowledge made possible the technological advances that allowed for the Industrial Revolution to take place (Christian, 2004). Indeed, as Mokyr (2000a) argues, 'in Britain the key to success was precisely in the ease by which manufacturers linked up with people who studied nature and to make the new ideas actually work on the shopfloor' (p. 18). For instance, the Scottish physicist and engineer William Rankine studied the mutually reinforcing developments in power technology and energy physics and translated his findings

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into a manual of the steam engine, which made it possible for engineers to access this technological knowledge and subsequently resulted in a multitude of improvements (Mokyr, 2004).

The emergence of a Newtonian culture was facilitated by the relatively pluralistic open culture and support of the Christian church, as well as the development of institutions where the mechanical science was taught and preserved. Both the Christian Church and the science institutions thus contributed to the dissemination and accumulation of knowledge throughout society (Chai, 2005). In the last decade of the seventeenth century, English clergymen began to preach Newton's natural philosophy with the aim of strengthening Christian belief (Jacob & Stewart, 2004). The clergies in Britain increasingly adopted the view that Newton's work helped to explain the purposes of God. For them, the mechanical nature of the laws which Newton advanced served to prove the intelligence of God's design (Bekar & Lipsey, 2004). In the Netherlands, by comparison, clergymen and the rest of society remained strongly opposed. Goldstone (2000) writes: 'While Calvinism in the seventeenth century may have produced scientific rationalists ... by the eighteenth century its orthodox clergy had grown fearful of heresy among the laity, and the power of Calvinist orthodoxy in popular culture produced widespread public opposition to the aspects of the new science' (p. 185). The Netherlands were not the only country in Europe in which resistance to the new science inhibited its spread. The attitude of the Church in Britain stood in marked contrast to the stance generally adopted in the rest of Europe. Bekar and Lipsey (2004) note: 'While Catholic and Protestant Clerics on the Continent were still opposing Galileo's theories, many Anglicans were preaching Newton's ideas from the pulpit' (p. 25).

In the period of mechanization leading up to the Industrial Revolution, a substantial cumulation of scientific and technological knowledge took place, so that practical knowledge became more easily accessible for those involved in the creation of new techniques (Mokyr, 2000a). Educational institutions had the vital role of preserving and spreading knowledge. In general, the British inventors received high levels of education and closely paid attention to the most recent scientific developments and breakthroughs (Bekar & Lipsey, 2004). Indeed, although many of the innovations were the products of practical workers rather than true scientists (Christian, 2004), Landes (1998) has brought to notice the considerable level of theoretical knowledge these practical workers possessed. The act of toleration in 1689 led to the emergence of an educational system relatively independent of the Anglican church, while in France for instances the colleges continued to be controlled by Christian priests (Jacob, 2000). The educated in France did not receive any formal education in Newtonian applied science and the Newtonian view on the world until the second half of the eighteenth century. French teaching thus missed the practical Newtonian mechanics which served the foundation for Britain's industrial success. The ability of the French to invent was no less, but what differentiated the British from the French is that they were exceptionally good in improving the production process, for they were taught the mechanical science that was required for putting ideas into practice (Bekar and Lipsey, 2004).

## Scientific attitudes in the civilizations of China and Islam

While the uniform orthodoxy in many European countries and the interference in education of the Church restrained the development of technological advances necessary for industrialization to take off, it did not prevent it. At the start of the nineteenth century the Newtonian culture began to take hold in the majority of countries in the north-west of Europe (Goldstone, 2000). Europe's institutions were already pre-adapted to accommodate the new approach. Indeed, to a large extent the difference among European countries had been one of degree and timing rather than of fundamental nature. Europe thereby became the first of the world's great civilizations that industrialized. The question arises why the civilizations of China or Islam, which both were among the world's most significant contributors to technological advance, were left behind (Nielsen, 2010). While the Chinese empire and Islamic regions were very close to experiencing an industrial revolution at the same time this took place in the West, they lacked the Western science, and Newtonian mechanics in specific, that underlaid many of the technological inventions on which the First Industrial Revolution was based. Moreover, there was no similar preservation of scientific knowledge in educational institutions that could have served for the accumulation and dissemination of scientific knowledge (Bekar & Lipsey, 2004).

Christian (2004) notes that many inventions were not made by scientists but rather by practical workers. He then argues that, instead of representing a response to the introduction of fundamental new techniques, the Industrial Revolution was rather a function of the existing technological knowledge that had accumulated up to the point at

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which the development of technologies made an industrial take off possible. But it was particularly in Europe where this point was reached. Indeed, Bekar and Lipsey (2004) state that while '(m)any other cultures, particularly those of Islam and China, have produced scientific and technological discoveries at least on par with those of Medieval Europe ... few have produced the capacity for the incremental cumulative advances in science seen in Europe' (p. 17). Institutions are in general necessary in order for scientific knowledge to be preserved, to be transferred from generation to generation, and to be built upon. The universities in Europe originating from the Medieval period largely served these functions. In the Chinese empire and in the Islamic region, there were no similar independent institutions for accumulating knowledge and generating scientific advances to the extent that was possible in Europe. While the accumulation of technical advances could be ensured through the embodiment of technological knowledge in artefacts that are continuously employed and therefore pass from generation to generation, there is no similar automatic memory in the case of scientific knowledge (Bekar & Lipsey, 2004). Institutions that preserve this kind of knowledge may therefore be critical for scientific successes to be made. Indeed, as Chai (2005) argues, the considerable differences in the science institutions provide an explanation for why the advent of modern science and subsequently the Industrial Revolution happened in Europe rather than in the Chinese empire or in the regions of Islam.

China not only lacked the widespread interest in Newtonian mechanics which proved so successful in the West, but also the investment in the study of science in general. As noted by Nielsen (2010), China's fruitful sources technological innovation were in many cases insufficiently institutionalized. It might be the case that, similar to the situation in Europe in which the spread of new science was initially restricted by Christian orthodoxy, the Confucian state in China inhibited the dissemination of new ideas through its emphasis on conservatism and maintaining the status quo. However, as Lin (1995) argues, the politico-ideological authority was not as rigid as to make impossible a scientific breakthrough. It is rather the incentive structure by which the educational institutions were characterized that prohibited an advance of modern science as experienced in the West. The Chinese educational system was organized around the preparation for civil service in which the educated would serve to administer the Empire. While the system was open to scholars from all layers in society, there was no teaching in science and all they were taught was non-mechanical. Attention was directed at promotion to the civil service and distracted away from the study of modern science. Mathematical hypothesizing and systematic experimentation were therefore to a large extent neglected. Thus, there was not the cumulation of engineering knowledge which had underlaid Europe's early factory phase (Lin, 1995).

The Islamic countries had once been taking the lead in science. However, after the fourteenth century, their level of scientific advances and technological innovations declined. By then, religious law was closely integrated with other types of law, and therefore these regions lacked a pluralistic culture in their political realm. Furthermore, the religious leaders opposed the reconciliation of new forms of scientific views with the religious doctrine of Islam. The development of independent effective institutions and attitudes in support of scientific research, free from religious authority, did not materialize. This contributed to the Islamic region failing to keep up after the fourteenth century in scientific and technological respect (Bekar & Lipsey, 2004).

## Conclusion

The Industrial revolution is one of the greatest and most complex leaps in human history. The factors for explaining why it started in Britain are many and, even with the benefit of hindsight, still not agreed upon. Underlying these factors are deeper attitudes and beliefs. The Newtonian culture has with little doubt supported the industrial process to take off. Newtonian science was based on a mechanistic view that promoted the drive to mechanize human behaviour at large scale. Through the spread of this view to the various layers of society, a Newtonian culture emerged. The emergence of this culture was facilitated by the pluralism of British society and support of the Christian church, and the development of institutions adept at accumulating and disseminating the new science. The other European countries, notably in the north-west, were rather quick to accommodate the Newtonian mechanics as well. After Britain's success, political and religious leaders on the Continent came to support the scientific study of mechanics. Pre-adapted institutions further facilitated its spread. Meanwhile, while the civilizations of China and Islam had been important contributors to technological innovation, they failed to develop institutions to support and promote scientific cumulative advances and did not adopt the particular Newtonian science that drove the West to

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mechanize human behaviour and that contributed to its success. The intellectual environment of the Chinese and Islamic empires appears not to have been fit enough to be the first civilizations experiencing an industrial take off. The absence of a Newtonian culture may in this regard contribute to a better understanding of why these great civilizations were not the first to industrialize.

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