The consensus is that modern economic growth was started by the British Industrial Revolution. As is well known, during the Industrial Revolution itself, growth was in fact fairly modest, but the sudden take-off of gross domestic product per capita after 1825 or thereabouts was made possible by a long period of laying the foundations. The transformation was tantamount to a phase transition, a sea change in the mechanics of economic growth, with technological progress gradually coming to dominate the process, accounting for its novel features. But what were these foundations exactly? This chapter addresses this issue of foundations.

Before doing so, two central points must be made. The first is that events like a cluster of macroinventions such as happened in the first decades of the Industrial Revolution are not altogether unique in history, neither in Europe nor elsewhere. Moreover, growth, as Eric L. Jones and many others have noted, was not a new phenomenon in nineteenth-century Europe. Many regions or groups had managed over the centuries to accumulate wealth, to produce surpluses beyond subsistence, as works of art, architecture, and science amply indicate. Yet none of these processes persisted; growth was always checked and eventually fizzled out. Often it was reversed, and societies declined and in a few cases, entirely lost their former wealth. The telling characteristic of modern growth is its sustainability, indeed its inextinguishability.

The second point is that the idea that the Industrial Revolution was “British” and that Europe was just a “follower” seems overstated and, in some sense, wrong. Some areas of Europe, such as Flanders, Alsace, and Switzerland, were able to follow Britain fairly quickly, and although a sense of inadequacy among contemporary continental Europeans in the first half of the nineteenth century when comparing their industrial achievements to Britain can be perceived, modern economic historians have been more cautious about this so-called continental backwardness. Such perceptions need to take into account the high toll that the political turmoil between 1789 and 1815 had on the economies of continental
Europe. Although these upheavals can be regarded as the price that the Continent had to pay to “catch up,” the gap between Britain and the Continent was never on the order of magnitude of the gap between the West and China or Africa.

What, then, was behind this transformation? Historians have engaged the issue now for a century, and little consensus has emerged. Two significant recent contributions by David Landes and Kenneth Pomeranz have divided the causal factors between culture and geography. Earlier, Jones provided a veritable smorgasbord of explanations, including the ingenious idea of the European “states system” which likened the fragmented political power in Europe to a competitive market, limiting the damage that rulers could inflict on their economies. Others have focused on “Western science” as the crucial variable. Still others blamed European imperialism, itself due to accident, and dismissed the entire event as episemomenal. These explanations have been vigorously criticized and vigorously defended.

It is odd that in this literature, the European Enlightenment plays such a minor role. In recent decades, the Enlightenment has not fared well in the view of historians, being held responsible for the horrors of the twentieth century by Theodor Adorno and Max Horkheimer and their contemporary postmodern epigones, such as John Gray. Among the oddest phenomena in modern historiography, indeed, are the vitriolic and nasty attacks on the Enlightenment, which, perversely, is blamed for modern-day barbarism but never credited for bringing about modern-day prosperity. On the contrary, the European Enlightenment would seem to be a natural candidate in explaining the great divergence. After all, its timing took place approximately in the century before the beginning of modern growth in Europe, and it was clearly a Western phenomenon, its success more or less confined to the countries that by 1914 constituted the so-called convergence club of rich industrialized countries. Yet economic historians must have felt uncomfortable with the Enlightenment as an explanatory factor—perhaps because it is a relatively amorphous and hard-to-define intellectual movement, perhaps because the Enlightenment was believed to be primarily “French,” whereas the Industrial Revolution was “British,” and perhaps because the connections among beliefs, intellectual conventions, and economic events are poorly understood.

In this chapter, I argue that the Enlightenment played an important, perhaps crucial, role in the emergence of modern economic growth. This is not to denigrate other factors altogether. The cotton industry, one of
The European Enlightenment, could not emerge without access to sources of raw cotton, so international trade cannot be disregarded. Monetary and financial elements in the story are obscured, as are demographic and other factors. But the Enlightenment had two major effects that I emphasize: it transformed the motivation for and dynamics of technological progress, and it altered the institutional mechanism through which technological change affected the economy. These two formed a synergy that was the very foundation of the “European miracle.”

The Enlightenment and the Growth of Useful Knowledge

The European Enlightenment was a multifaceted phenomenon concerning the natural rights of humans, concepts of religious and racial tolerance, political freedom, legal reform, and much else. At the deepest level, the common denominator was the belief in the possibility and desirability of human progress and perfectibility through reason and increasing knowledge. The material aspect of this belief followed in the footsteps of Francis Bacon’s idea of understanding nature in order to control it. “Useful knowledge” became the buzzword of the eighteenth century. This term should not be associated simply with either “science” or “technology.” It meant the combination of different kinds of knowledge supporting one another. Not all of it was abstract science: the taxonomic work of Linnaeus and the descriptive writings of Arthur Young increased useful knowledge just as much as the abstract mathematics of Laplace or the experiments of Priestley and Lavoisier.

The eighteenth century marked both an acceleration of the pace of research and a growing bias toward subject matter that, at least in principle, had some practical value. Indeed, Peter Burke has argued that the eighteenth century saw the rise of “the idea of research” along with a sense that this knowledge could contribute to economic and social reform. The change in the pace of the progress of knowledge after 1680 was indebted to the triumph of Newtonianism in the first half of the eighteenth century. The achievement of Newton did more than anything else to establish the prestige of formal science in the world of learning. It was widely believed that the growth of useful knowledge would sooner or later open the doors of prosperity—to some extent with more hope than experience. But it was also clear that this growth could only be carried out collectively, through a division of labor in which specialization and expertization were carried out at levels far higher than before. The way useful knowledge increased in the eighteenth century was a far cry from
the processes of today’s R&D (corporate and government). It might be better to say that much of it was by way of exploration and discovery. These were trial-and-error processes minimally informed by an understanding of the natural processes at work, inspired tinkering, and a great deal of serendipity and good fortune, albeit favored by prepared and eager minds. Over the course of the eighteenth century, these search processes became more systematic, careful, and rigorous. New technological methodologies were invented, such as the great engineer John Smeaton’s development of the method of parameter variation through experimentation, a systematic way of making local improvements in a technique without necessarily understanding the underlying science.¹¹ To be sure, there were no truly fundamental scientific breakthroughs in the century between Newton and Lavoisier, but it was an age of consolidation, refinement, and organization of knowledge; the honing and sharpening of mathematical and experimental methods; and an age of observation, classification, and the jettisoning of doomed searches and projects.¹²

Hopes for a quick technological payoff to scientific research were, on the whole, disappointed in the eighteenth century. The “customary chasm” between science and the mundane details of production could not be closed in a few decades or even in a century.¹³ One can, of course, find examples in which scientific insights did enrich the knowledge of key actors in the Industrial Revolution. Dexterity and mechanical intuition were, in many cases, complementary to certain critical pieces of scientific knowledge that guided and inspired the work. The scientific milieu of Glasgow in which James Watt lived contributed to his technical abilities. He maintained direct contact with the Scottish scientists Joseph Black and John Robison, and as H. W. Dickinson and Rhys Jenkins noted in their memorial volume, “one can only say that Black gave, Robison gave, and Watt received.”¹⁴ The introduction of chlorine bleaching and the solution of the longitude problem (i.e., how to determine longitude at sea) depended to some extent on advances in science, and formal hydraulics contributed to advances in waterpower.¹⁵ Yet when all is said and done, much of the progress we associate with the First Industrial Revolution needed little more than the mechanics that Galileo knew, and innovation in manufacturing and agriculture before 1800 came without science providing indispensable inputs. William Cullen, the leading chemist of the mid-eighteenth century, was retained by Scottish manufacturers to help them solve a variety of problems. His self-serving prediction that chemical theory would yield the principles that would direct innovations in the practical arts remained, in the words of the
leading expert on eighteenth-century chemistry, “more in the nature of a promissory note than a cashed-in achievement.”16 Manufacturers needed to know why colors faded, why certain fabrics took dyes more readily than others, and so on, but as late as 1790, best-practice chemistry was incapable of helping them much.17 In medicine, in metallurgy, and in agriculture, to name just a few areas, the situation before 1800 was no different. The world may have been messier and more complex than the early and hopeful proponents of the Baconian program realized, as H. Floris Cohen has suggested.18 Scientists did not know enough and lacked the tools to learn quickly. Tacit artisanal knowledge, such as mechanical dexterity, intuition, experience-driven insights, and similar abilities, drove many of the early inventions, although dismissing the contribution of science altogether is unwarranted.

And yet the belief that somehow useful knowledge was supposed to be the key to economic development not only did not fade as a consequence of such disappointments, it kept expanding on both sides of the Channel. The Baconian “program” was built on the belief that the expansion of useful knowledge would solve technological problems and that the dissemination of existing knowledge to more and more people would have substantial efficiency gains. These two notions formed the core of Denis Diderot’s beliefs, and his admiration for Bacon, the first philosopher to lay out clearly a technological program for economic expansion, permeates his writing, as it does that of many other eighteenth-century philosophes and scientists. In Britain, of course, this belief was not only widespread but formed the explicit motive for the foundation of organizations and societies designed to advance it.19

Progress was limited simply by what people knew. The age of Enlightenment, for instance, never had a good concept of what “heat” really was. Its chemistry was, until the 1780s, anchored in phlogiston theory, and its understanding of biology and disease, despite some significant local advances, had progressed little beyond Galen. Newton’s great insights, much as they supported the belief that rational argument and observation could help people understand the universe, were of limited practical value. Yet it was also readily recognized that very intelligent people, schooled in experimental science and mathematics, could make substantive contributions to technology even if they were not always quite sure why and how new techniques worked. Thus mathematicians were asked to solve mundane and practical problems, and sometimes they were successful.20 Other examples are easy to find.21 From the measurement of longitude (perhaps the best-defined single problem that the age
of Enlightenment solved) to the improvement of waterpower by applying mathematics to the growing science of hydraulics, the knowledge of various “applied philosophers” was brought to bear on matters of technology. The same is true for knowledge of plants and animals. Many scientists were concerned with the properties of steel: René Réaumur and Torbern Bergman wrote about them at length, recognizing their economic significance, and three of France’s most learned men published a paper in 1786 establishing once and for all the differences among wrought iron, cast iron, and steel—even if the full effects of this insight were still decades in the future.

Many men of science applied themselves to invention. Most of them applied notions of “open science” to their inventions and placed the knowledge in the public realm. Benjamin Franklin, Humphry Davy, Joseph Priestley, and Benjamin Thompson (Count Rumford), four of the leading scientists of the later decades of the age of Enlightenment, made numerous inventions, but refused to take out any patents, arguing that their efforts were made for the benefit of humanity, not for private profit. Such hybrid careers became common in the nineteenth century. Michael Faraday, besides his pathbreaking research on electricity, worked on various problems in materials, especially steel and glass. Eda Kranakis emphasized the work of the French engineer and mathematician Claude-Louis Navier (1785–1836), who, among others, used the recently developed Fourier analysis to analyze the vibration in suspension bridges and did pioneering work in fluid dynamics for which he is still known. His work, and that of other polytechniciens, was highly abstract and mathematical, and it was of long-term rather than immediate applicability. Not so that of Lord Kelvin, a prolific inventor who owned seventy patents in electromagnetic telegraphy, marine navigation equipment, and electric instruments.

The connection between the sphere of learning and the sphere of production has always been a sensitive spot in the history of economic growth. Narrowing this gap was perhaps the crowning achievement of the industrial enlightenment. Part of the contact between the two spheres took place through books and periodicals and part of it through direct contact and transfer of knowledge through teaching, imitation, and espionage. The publication most widely associated with the Enlightenment, Diderot and d’Alembert’s Encyclopédie, contained numerous articles on technical matters that were lavishly illustrated by highly skilled artists who in most cases were experts in their fields. Encyclopedias and indexes to “compendia” and “dictionaries” were the search engines of the eighteenth
century. In order to be of practical use, knowledge had to be organized so that it could be selected from. Alphabetization was one way to do this, the organization of science into categories another.\(^{27}\)

The eighteenth century also witnessed improved codification of formerly tacit knowledge. Part of this process was simply the improvement of the language of technology: mathematical symbols, standardized measures, and more universal scales and notation all added greatly to the ease of communication. Post-Lavoisier chemical nomenclature proposed by the Swedish chemist Berzelius in 1813 was agreed on after some hesitation. When new measures were needed, they were proposed and accepted. Thus, as is well known, James Watt proposed in 1784 the total amount of energy necessary to raise 33,000 pounds one foot in one minute as the fundamental unit of work, the horsepower.\(^{28}\) Visual means of communication, above all diagrams and models, were vastly improved.\(^{29}\) In addition, between 1768 and 1780, the French mathematician Gaspard Monge developed descriptive geometry, which made graphical presentations of buildings and machine design mathematically rigorous.\(^{30}\) When human presence was required, travel became faster and more comfortable during the eighteenth century. The idea of the traveling expert or consultant was exploited by Boulton and Watt, whose patent-based monopoly on steam power extended to consulting on energy and mechanics. John Smeaton was perhaps the greatest consultant of all, founding the Society of Civil Engineers, but others followed his example.\(^ {31}\)

Knowledge was also transferred through personal contacts and lectures. The years after 1660 witnessed the founding of many state-sponsored, official academies such as the Royal Society, but these were always complemented by private initiative. Early in the eighteenth century, many of those lectures were informal and ad hoc, in pubs and coffee-houses.\(^{32}\) After 1750, many of those informal meeting places crystallized into more formal organizations and societies, some of them with official imprimaturs. Of those, the Lunar Society of Birmingham is the best documented,\(^ {33}\) but the Chapter Coffeehouse in London was equally successful as a clearinghouse for useful knowledge.\(^ {34}\) Other organizations were more formal. The Royal Society of Arts, founded in 1754, encouraged invention by awarding prizes, publicizing new ideas, and facilitating communication between those who possessed useful knowledge and those who could use it. The Royal Institution, founded by Count Rumford and Joseph Banks in 1799, provided public lectures on scientific and technological topics. Its charter summarized what the industrial enlightenment was about: “diffusing the knowledge, and facilitating the general
introduction, of useful mechanical inventions and improvements; and for
teaching, by courses of philosophical lectures and experiments, the appli-
cation of science to the common purposes of life.” As James McClellan
noted, the reason for all this institutional innovation was simple: it was
perceived as useful.\textsuperscript{35}

In the eighteenth century, alternatives to the universities emerged.
The most dynamic elements in the English educational system were the
dissenting academies, which taught experimental science, mathematics,
and botany among other subjects.\textsuperscript{36} On the Continent, new institutions
training technical experts came into being, many of them under govern-
ment sponsorship. Two of the famous French \textit{grandes écoles} were founded
in the eighteenth century: Ponts et Chaussées in 1747 and Mines in 1783.
In Germany, the famous mining academy of Freiberg (Saxony) was
founded in 1765, followed by others in the 1770s. All these institutions
reached only a thin elite, though apparently that was enough. In general,
the idea that the role of educational institutions was to create new knowl-
edge rather than transmit existing knowledge to young generations took
a long time to ripen. The belief that the Industrial Revolution in its early
stages required mass education and literacy has long been abandoned. The
British apprenticeship system with the educational institutions mentioned
above was more than enough to supply British industry with the skills
and craftsmanship it needed. The Industrial Revolution was an elite phe-
nomenon: not, of course, just the handful of heroic inventors as worship-
ful or adulatory Victorian writers in the Smiles tradition of self-help would
have it, but a few tens of thousands of clever and dexterous mechanics
and skilled craftsmen who read blueprints, knew the properties of the
materials they used, built parts according to specification within reasonable
tolerance, had respect for precision, and had the experience to understand
friction, torque, resistance, and similar concepts. For the rest of the labor
force, education and literacy may not have mattered much, and Britain
had no advantage in this domain.

The Enlightenment and Institutional Progress

Economists have lately realized what economic historians have known all
along: that “good institutions” are essential to successful economic growth.
In recent years, a genuine avalanche of empirical work has pointed to the
centrality of property rights, incentives to innovation, the absence of
arbitrary rule, and effective contract enforcement, to name but a few oft-
mentioned institutional elements.\textsuperscript{37} Yet these studies tend to exploit cross-
sectional variation and do not bother much with how Europe acquired these good institutions.

The economic significance of the political and institutional reforms of the late eighteenth and early nineteenth centuries has not been fully realized in part because of the undue focus on the security of property rights without much attention to the exact content of these rights. This view overlooks the fact that ancien régime Europe was overgrown with secure and well-enforced local privileges, tax exemptions, monopolies, exclusionary rights, regulations, entry barriers, limited freedom of occupation, and similar arrangements that hampered markets, impeded technological progress, and threatened economic growth wherever it was attempted. In other words, what needed to be done was to eliminate bad rights and contracts.

Mercantilism, the organizing principle of the ancien régime economy, was based on the assumption that economic activity was zero sum. Both at the aggregate level and at the levels of the firm and of the individual, the ruling economic paradigm was one of a fixed pie, and the more one player got, the less there was for others. The idea that production and commerce actually could expand as the result of free exchange ripened slowly in the age of Enlightenment, coming to a crashing crescendo with the Scottish Enlightenment of Hume and Smith and the French économistes of the physiocratic school. As observed persuasively by Robert Ekelund and Robert Tollison, the mercantilist economy was to a great extent a rent-seeking economy, in which the incentive structure was largely designed for redistributive purposes.

It is possible to regard the age of Enlightenment partly as a reaction to the economic ancien régime. This is less far-fetched than it may sound. Enlightenment thought increasingly railed against the institutions that perpetuated rent seeking. It should be noted that many of those institutions had not originally been designed as rent-seeking institutions but eventually evolved into them. A paradigmatic example is the craft guild. Craft guilds in the eighteenth century, as Adam Smith argued forcefully, were costly to economic progress. They erected artificial barriers to entry in order to reap exclusionary rents, and on the whole they were hostile to new technology. The success of Britain, where guilds had been relatively weak since the mid-seventeenth century, seemed to confirm this belief. The literature on this matter has in recent years been subject to some serious revisionism, especially by S. R. Epstein. Guilds were not invariably hostile to innovation, this literature argued, and in many ways, they helped in the formation and intergenerational transmission of human
capital. Sheilagh Ogilvie has cast doubt on this revisionist literature and shown that, for Württemberg at least, the negative view of craft guilds is supported by a great deal of historical evidence. The overall evidence is more mixed: some guilds were more powerful than others, and it seems that their actual functions changed over time. By 1750, in most places, they had become conservative and exclusionary, and it seems hard to imagine that radical innovation would have had much of a chance had they still been in control. Whenever guilds tried to maintain product-market monopolies, their incentives to innovate were lower than in a competitive market, and their incentives to protect their knowledge—through secrecy and limitations of the mobility of skilled labor—higher. This clearly had profound economic costs.

Abolishing or weakening craft guilds was a high priority for enlightened reformers, precisely because guilds were viewed as impeding efficiency and economic growth. Attempts to carry out such programs were in fact attempted before 1789 by reform-minded politicians such as Turgot in France, Sonnenfels in Austria, and Campomanes in Spain. Jeff Horn has pointed out that the reformist elements in the ancien régime in France needed to overcome the collective action of both masters and employees in French manufactures to create an environment more conducive to technological advance and productivity growth. But all these attempts ran into stiff resistance, in part from the vested interests (of employees and industrialists alike) threatened by such reforms, but also in part because the rents that guilds collected were partially dissipated to the government and the fiscal consequences were often serious. Nothing but shock treatment could work, and on February 16, 1791, the French guilds were abolished by fiat of the National Assembly. When Revolutionary French armies advanced into the Low Countries, Italy, and Germany, this reform was invariably imposed. Although the suppression of the guilds did not lead to completely free labor markets and resistance to new technology in France could still be strong on occasion, by the time the dust settled on the Continent in 1815, this vestige of the economic ancien régime had been fatally weakened. By itself, the suppression of the guilds cannot be regarded as a necessary condition for economic growth: long before 1791, manufacturers were able in many cases to move out of towns controlled by guilds, employ women and children, and find other ways around guild restrictions. But as a symptom of a general change in the attitude toward rent seeking, the history of craft guilds is illustrative.

Commercial policy was at center stage of enlightened antimercantilist policy. Here too there was ambiguity. Not all Enlightenment writers
were unambiguously pro–free trade. Yet the theme of trade being a positive-sum game, so eloquently expounded by Adam Smith, had been advocated since the late seventeenth century and was becoming dominant in political economy by 1800. It is ironic, of course, that the wars of 1793–1815 caused by the French Revolution and its aftermath seriously disrupted international trade, leading David Ricardo, the greatest mind of early-nineteenth century political economy (an offshoot of the Enlightenment), to include an entire chapter devoted to this phenomenon. With the exception of a brief interlude following the 1786 Eden Treaty, free trade was not to be seriously considered as a policy option until the 1820s. Smith himself was not optimistic about free trade being established in Britain any more than “that Oceana or Utopia be even established in it.” Yet the pax Britannica and the slow turn toward freer trade between 1820 and 1880 cannot be seen as the outcome of economic interests alone; persuasion on logical grounds was very much part of the story. The *Wealth of Nations* may not have killed mercantilism with a single blow, but it clearly pushed it into a defensive corner.

What is not always realized, however, is that the main triumph of the free trade doctrine was the establishment of free internal trade. Enlightenment thinkers viewed internal tariffs as the rent-seeking abomination they were, and the elimination of the French internal tariff barriers followed the abolition of the guilds. The U.S. commerce clause had been inserted into the U.S. Constitution a few years earlier. Internal trade in Sweden was liberalized in the late 1770s. In Germany, the matter was more complex, but the post-1815 movement toward a German *Zollverein* reflected the same sentiment. The system of tolls and duties on Germany’s magnificent river system that hampered trade in the eighteenth century was dismantled. Arguably the lion’s share of gains from trade was secured through internal rather than external trade.

Did these ideological changes have an effect? It is hard, in the end, to be sure that Enlightenment thought was more than Saint-Exupéry’s king who commanded the sun to rise every morning. John Stuart Mill’s statement that a good cause seldom triumphs unless someone’s interest is bound up with it does not imply that, at times, such good causes do not fail. Enlightenment-inspired reforms in the West came in four waves. First, there were the post-1750 reforms introduced by so-called enlightened despots, which were often inspired by the writings of the *philosophes*, but rarely had much staying power since they frequently ran up against deeply entrenched interests. Second, there were the “natural reforms” introduced in countries that had meta-institutions such as a Parliament
with sufficient political adaptiveness to bring about induced institutional change. Britain was able to pass such “rational” legislation as the Turnpike Act, the East India Acts of 1784 and 1813, the abolition of the Statute of Apprentices and Artificers in 1809, and the Navigation Acts in 1849. In other countries, revolution, whether indigenous or imported, was necessary. Finally, there were reactive reforms in countries such as Prussia as a result of reforms in nations viewed as competitors. The Enlightenment’s influence on the French and American revolutions needs no elaboration. Equally well documented is the enormous influence that the Wealth of Nations had on policymakers, especially after Dugald Stewart, Smith’s successor at Edinburgh, turned the book into a fountainhead of wisdom.\textsuperscript{51} Among Stewart’s pupils were two future prime ministers, Henry Palmerston and John Russell, as well as other senior officials, such as William Huskisson, the prime mover in the British liberal reforms of the 1820s. His program was to remove all state support and protection for manufacturing and agriculture. Huskisson “zealously and consistently subscribed” to the theories of Adam Smith. “Smith’s teaching is reflected in practically every reform in the twenties.”\textsuperscript{52} In Germany, the influence of “the Divine Smith” on Prussian reformers has been thoroughly documented.

In economic history, scholars often write of technological progress but rarely of institutional change, and for good reason. But it could be argued that in the century after 1750, there was something we might think of in those terms, because this was the age when rent seeking in Europe was losing ground to productive commerce and production, markets became a little freer of regulation, and taxation and economic policy became less distributive. That it did not produce laissez-faire economies, even in Victorian Britain, and that the movement was full of reversals and ambiguities requires no repetition. Britain’s technological successes prompted a very unenlightened set of laws prohibiting the exportation of machinery and emigration of skilled artisans (which, however, did little to stop the flow of useful knowledge). The French Revolution, despite its overall commitment to Enlightenment values, triggered a serious reactionary backlash in Britain, and, in France itself, the Academy of Sciences was closed in 1793 by the Jacobins, who felt that “the Republic does not need savants.” But “progress” there was all the same. The quarter-century between the Bastille and Waterloo was in some ways a \textit{réculer pour mieux sauter} (take a step back in order to advance) kind of interlude. By the late 1820s, mercantilism had retreated, and serious growth could occur.
The long-run historical significance of this advance was that it eliminated the negative institutional feedback that had wiped out economic growth before 1700. It is easy to see a counterfactual scenario in which the economic gains of the mule, the Watt engine, and the puddling and rolling process were swallowed up by tax collectors, wars, protectionists, and distributive coalitions of various kinds. It is not hard to imagine the newly entrenched technological status quo becoming increasingly more conservative and resisting further technological advances through political action. That this did not happen is the result of the double action of the Enlightenment: while it increased useful knowledge and its effectiveness, at the same time it improved the incentives for its implementation and weakened the forces that would set it back. In that sense, Enlightenment-inspired technological progress and institutional change created a powerful synergy, which in the end was responsible for the sustainability of what started in Britain in the last third of the eighteenth century and its diffusion to the societies that shared the Enlightenment.

The Roots of the European Enlightenment

Attributing the emergence of modern growth in the West to the Enlightenment in Europe leaves the question of the roots of the Enlightenment itself unanswered. To put it bluntly, we need to ask why Europe had an Enlightenment and other cultures such as Islam or China did not. Answering this question satisfactorily would be a huge undertaking. Linking it to previous events such as the emergence of humanism in Renaissance Europe or the Reformation only pushes the question further back in time. An alternative approach is not to ask why Europe had an Enlightenment, but to postulate that “enlightened” ideas occurred in all societies and that only in the “West” was this movement successful in the fashion I have described. The victory of the Enlightenment was not just a case of a growing and cumulative store of knowledge, but the triumph of open and public knowledge over secret “arcane” knowledge, the victory of “mechanical” philosophy (e.g., verifiable knowledge about natural regularities) over “occult philosophy” dealing with mystical and unobservable entities. How, then, did the good guys win?

Europe’s uniqueness was obviously not that it was monetized, commercialized, and enjoyed “good” governance. “Capitalism”—whatever may be exactly meant by that term in the context of early-eighteenth-century Europe—seems too vague a concept to be of much help. What
seems unique to Europe in the period leading up to and including the Enlightenment is the growing opportunity for critics, skeptics, and innovators to try their ideas out in a marketplace for ideas and to survive the experience. The notion that Europe was deeply hostile to “heretics” based on the tragic experience of such figures as Giordano Bruno and Miguel Servetus is fundamentally mistaken. The picture of Europe in the period 1500–1750 is one in which innovative, often radical, intellectuals were able to play one political authority against another, different polities against each other, and, when necessary, to take advantage of central versus local power, the private against the public sphere, and spiritual against secular authority. By moving from one place to another when the environment became too hostile, the members of the intellectual class (“clerisy” as they are sometimes called) could remain active in the transnational community of scholars—the Republic of Letters. Iconoclastic scholars who brought the ire of the local establishment on themselves usually went elsewhere. Martin Luther and Paracelsus are the most famous rebels who successfully played this game. For the West as a whole, the salutary effects of this pluralism cannot be overestimated. David Hume, for one, felt that this was the main reason why the sciences in China “made so slow a progress.” In China, he argued, “none had the courage to resist the torrent of popular opinion, and posterity was not bold enough to dispute what had been universally received by their ancestors.”

The fragmentation of power and the competitive “states system” (Jones’s term) is slightly anachronistic for the principalities and bishoprics that enjoyed considerable political autonomy in the seventeenth and eighteenth centuries. Paul David has argued that many rulers competed to attract to their courts reputable scientists, in part because some skills could come in handy, but largely as a signaling device (that is, to show off). The competition for the “best” scientists between European rulers required open science as a solution to the asymmetric information problem that rulers faced: to identify the truly leading scientists of their generation. Only within communities (“invisible colleges”) in which full disclosure was exercised, he argues, could credible reputations be established that would allow wealthy patrons to separate truly distinguished scientists from fraudulent ones. Open science then emerged as a better strategy for scientists competing for patronage. The competition of different institutions for the superstars of science meant that the very best could set their own research agendas and appropriate the benefits of research, such as they were, and that few governments had the power to suppress views they considered heretical or subversive.
We may also point to specific institutional changes that encouraged both the growth of intellectual innovation and its growing bias toward “usefulness,” though the latter term needs to be treated with caution. Perhaps the central development was a change in the relationship between the world of production—farmers, merchants, manufacturers, as well as government agencies engaged in military and infrastructural projects—and the world of intellectuals. The idea that *ars sine scientia nihil est* (practice is worthless without theory), first enunciated in Renaissance Italy, slowly won ground. Natural philosophers were increasingly retained and engaged in practical matters where, it was believed, they could use their knowledge of nature to solve problems and increase efficiency. The growing conviction that this knowledge had (at least in expectation) a positive social marginal product meant, of course, that the demand for useful knowledge increased. This created the standard problem of intellectual property rights for the spread of useful knowledge. The interesting way in which this was solved was by taking advantage of the fact that the creators of propositional knowledge sought credit rather than profit from their work. Such credit, in some cases, was necessary to assure them of some reservation price, mostly in terms of a sinecure: a pension, an appointment at a court or a university, or a sponsored job by an academy or scientific society.  

The rules of the game in the Republic of Letters, as they were established in the second half of the seventeenth century, were credit by priority, subject to verification. This “credit” was a property right in that it attributed an innovation unequivocally to the person responsible. Enhanced prestige was then often correlated with some appointment that provided the scientist with a reservation price, though the correlation was far from perfect. Others, such as Henry Cavendish, Joseph Banks, and Antoine Lavoisier, were financially independent and did not need or expect to be compensated for their scientific work.

The other factor that facilitated the success of the Enlightenment as an intellectual movement in Europe was the institutional fluidity of intellectual activity. No single set of institutions dominated thought in Enlightenment Europe the way the Roman Catholic Church had dominated in the medieval period and the way the Confucian mandarinate dominated Chinese thought. In Europe, such institutional domination was absent, and within the Republic of Letters there was free entry and furious competition for patronage and clients. Peter Burke has suggested that universities tended to suffer from “institutional inertia” and became conservative over time, so that only the founding of new ones kept them creative and lively.  

Professor Martin Luther was teaching theology at an institution
that was only fifteen years old, and the University of Leyden, founded in 1575 as a Calvinist University, became a major curricular innovator. But universities had to compete with the academies and courts of Europe to attract the best minds of Europe. The decentralized and multifocal distribution of wealth and power in Europe between Luther and Lavoisier led to a world of intellectual competition in which knowledge was both transmitted and augmented in ever more effective fashion.

There were other reasons for the success of the European Enlightenment. The *philosophes* of the eighteenth century were not a marginal group struggling for recognition. Despite their opposition to the existing arrangements and their dreams of reform and improvement, they were more often than not part of the establishment or, more accurately, part of some establishment. The triumph of the *philosophes* must be explained by their ability to act against the status quo from within the establishment. Many of the leading *philosophes* and political economists were well born and politically well connected. Even when they ran afool of the regime, the relations rarely degenerated into hostility. This “cozy fraternizing with the enemy,” as Peter Gay calls it, did not come without a price, but it allowed the *philosophes* to be politically effective without necessarily threatening the status quo. In France, this relationship ultimately imploded (though it was soon restored), but elsewhere, it enabled their ideas to be adopted by the men who voted on policy decisions. All the same, throughout Europe, the Enlightenment was a decentralized and free-enterprise endeavor, sometimes tolerated but rarely managed or sponsored by governments. Yet it was not unorganized: enlightened ideas found expression in the myriad of friendly societies, academies, Masonic lodges, and similar organizations of people who shared beliefs and traded knowledge. To be sure, there were a few figures of political power who were associated with and influenced by the Enlightenment, the best known of whom were the so-called enlightened despots and some of their ministers. It stands to reason that an intellectual movement such as this can fail either because it is too close to the government or because it is so marginalized that it can be ignored. Much of the European Enlightenment fell in between.

The European Enlightenment pushed a dual platform that was radical and revolutionary: reform institutions to promote efficiency and innovation, and bring the full force of human knowledge to bear on technology. Without that synergy, long-term economic growth in the West might not have happened either. The Enlightenment was an indispensable element in the emergence of modern economic growth. Its belief
in social progress through reason and knowledge was shocked repeatedly as the superiority of reason was thrown in doubt. But the idea of useful knowledge as an engine of social progress has not lost any of its power, even as it has been challenged, toned down, and refined in the two centuries since 1800. There was nothing preordained or inevitable about that course of history. Indeed, in hindsight, it seems rather unlikely, and any competent economic historian can point to a dozen junctures where the process could have been derailed. The fruits of these changes were, of course, very late in coming. Economic growth, in the sense that Robert Lucas had in mind, does not take off anywhere before 1830. And yet from a long-term perspective, the striking thing is not that it happened so long after the necessary preceding intellectual changes but that it happened at all.

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Notes


7. This point has been well made by Ian Inkster, “Potentially Global: A Story of Useful and Reliable Knowledge and Material Progress in Europe, ca. 1474–1912,” *International History Review* 18 (2006), 237–286, whose analysis parallels what follows in certain respects. Inkster proposes the term URK (“useful and reliable knowledge”), which is much like the term proposed by Simon Kuznets who preferred “testable.” In my view reliability is an important characteristic of useful knowledge, but it seems less crucial than tightness, that is, the confidence and “consensualness” with which certain knowledge is held to be “true.”


13. The term is from Cohen, “Inside Newcomen’s Fire Engine,” 118, who adds that in the seventeenth century, useful applications of the new insights of science kept eluding its proponents.


22. Leonhard Euler, the most talented mathematician of the age, was concerned with ship design, lenses, and the buckling of beams; with his less famous son Johann, he contributed a great deal to hydraulics.

23. The three were Alexandre Vandermonde, Claude Berthollet, and Gaspard Monge, who jointly published their “Mémoire sur le fer,” under the influence of the new chemistry of their master, Antoine-Laurent de Lavoisier.


38. This is precisely captured by Adam Smith: “[N]ations have been taught that their interests consisted in beggaring all their neighbours. Each nation has been made to look with an invidious eye upon the prosperity of all the nations with which it trades, and to consider their gain as its own loss.” *An Inquiry into the Nature and Causes of the Wealth of Nations*, ed. Edwin Cannan (Oxford: Oxford University Press, 1976 [1776]), 519.


41. The canonical statement is by the great Belgian historian Henri Pirenne: “The essential aim [of the craft guild] was to protect the artisan, not only from external competition, but also from the competition of his fellow-members.” The consequence was “the destruction of all initiative. No one was permitted to harm others by methods which enabled him to produce more quickly and more cheaply than they. Technical progress took on the appearance of disloyalty.” *Economic and Social History of Medieval Europe* (New York: Harcourt, 1936), 185–186. For similar statements, see Carlo Cipolla, “The Economic Decline of Italy,” in *Crisis and Change in the Venetian Economy in the Sixteenth and Seventeenth Centuries*, ed. Brian Pullan (London: Methuen, 1968); Pierre Deyon and Philippe Guignet, “The Royal Manufactures and Economic and Technological Progress in France before the Industrial Revolution,” *Journal of European Economic History* 9:3 (1980), 611–632; Jeff Horn, *The Path Not Taken: French Industrialization in the Age of Revolution, 1750–1830* (Cambridge, MA: MIT Press, 2006), chap. 2.


44. Horn, *The Path Not Taken*, chap. 2.


50. The Zollverein was preceded by the Prussian Maassen Tariff Law of 1818, which abolished all internal tariffs in Prussia and was influenced by a memorandum by G. J. C. Kunth, Beuth’s mentor.


55. The economics of open science resemble in many ways the economics of open source software development, which has found that signaling to outsiders, peer recognition, and direct benefits all play a role. Josh Lerner and Jean Tirole, “The Economics of Technology Sharing: Open Source and Beyond,” NBER working paper 10956 (December 2004).

56. In an earlier time, the absence of clear-cut rules discouraged open knowledge. Thus the architect Francesco di Giorgio Martini (1439–1501) complained that “the worst is that ignoramuses adorn themselves with the labors of others and usurp the glory of an invention that is not theirs. For this reason the efforts of one who has true knowledge is oft retarded.” Cited by William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton, NJ: Princeton University Press, 1994), 88.


60. Indeed, even during the Enlightenment, the supremacy of reason over sentiment and sensitivity has been shown to be a flawed concept. Jessica Riskin, *Science in the Age of Sensibility: The Sentimental Empiricists of the French Enlightenment* (Chicago: University of Chicago Press, 2002), 200.