The Commons of Knowledge: A Historical Perspective

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Knowledge is a classic commons problem. As Elinor Ostrom and Charlotte Hess (2007: 41) point out, knowledge is a shared resource, but it is quite different from the main focus of Ostrom's work, which was resources that were common but depletable (such as land, clean air, and water). Knowledge is what economists would call a "classic non-rivalrous or non-subtractable good," in which adding a marginal user does not reduce the consumption of other users. As a result, there is no danger of overexploitation (Bollier 2007). The main danger is not a "tragedy of the commons" kind of problem but underproduction. Because knowledge is also characterized by high exclusion costs, meaning that it is difficult to force people to pay for knowledge once it is produced, there is a serious danger of consistent underproduction of useful knowledge, as Arrow pointed out half a century ago (Arrow 1962).[2] This highlights a deep and pervasive difficulty in the economic history of the Industrial Revolution. If it is granted that modern growth is characterized by being increasingly propelled by technological change, that is to say, advances in *useful knowledge*, what kind of institutions resolved the commons problem?

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[2] As David (2004a: 577) notes, the "appropriability problem" emphasizes that openness in science sets the stage for market failure due to free-riding problems. While this is not quite identical to the commons problems emphasized by Ostrom, the similarities are quite striking (Hess and Ostrom 2007: 4–5).

The answer should be found in Western Europe in the era just preceding the Industrial Revolution, that is to say, 1600-1750. The culture and institutions of useful knowledge changed in this era, and helped create an edifice of rapidly growing knowledge that sooner or later was brought to bear on production technology. In the eighteenth century, this movement culminated in what I have called the *Industrial Enlightenment*: a transnational movement toward the creation, dissemination, and application of experimental philosophy (as contemporaries referred to what we would call science) to the "useful arts" (see Mokyr 2002, ch. 2 and Mokyr 2009, chs. 2-4). Some of this knowledge turned out be quite effective, but it is equally true that some of the central inventions of the Industrial Revolution required no more scientific insight than what Archimedes knew.

But generating that useful knowledge was far from a trivial matter precisely because of the appropriability issues mentioned above, and it is perhaps not surprising that of all the societies that ever existed, it was only Western Europe after 1600 that managed to create the conditions for this knowledge to accumulate at an ever rapid pace, enough to eventually affect every aspect of production. To understand how and why this happened, it helps to rely on Ostrom's insight of the notion of a community-management of a commons resource. My argument here is quite simply that such a community emerged in post-renaissance Europe, and that it was essential in creating the useful knowledge necessary for sustained economic growth. Such an outcome may have seemed unlikely at first: Europe was enormously fragmented politically, and managing any resource by a public institution on more than a local scale seems to be beyond the power of any entity. Not only that much of the Continent was divided amongst small units, but even those that were ostensibly combined in larger political units had to cope with the virtual autonomy of many of their constituent parts.

The community in question was known in its time as the *Respublica Literaria* or the Republic of Letters (Daston 1991; Brockliss 2002; Darnton 2003). The Republic of Letters, as Ian MacLean (2008: 17) points out could be seen from different angles: a community of scholars, the content of the ideas they fostered, the means of disseminating them, as the institution that set standards of persuasion (adequacy of proof, reproducibility of experiment), attitudes to collaboration and disclosure, and so on. For my purposes here, it can be compared to the communities that set social norms and informal rules that led to a cooperative outcome that turned out to be Pareto-superior. This is not to argue that it came into being or persisted *because* it was superior. But whatever brought it about,

it turned out an institution unique in human history and, in the end, a key to understanding where the long road that led to the "European Miracle" began.

While its beginnings as a major intellectual institution can be dated to the earlier days of Erasmus of Rotterdam (MacLean 2008: 18), the Republic of Letters clearly reached full maturity in the early decades of the Enlightenment, 1680-1720 (Ultee 1987: 97).[3] It was above all a *virtual* community: it had no formal institutions, no annual congress, did not publish its own periodical, and yet it managed to create and enforce a substantial number of rules that amounted to the emergence of open science in Europe. The members of the community were highly educated, and with few exceptions literate both in Latin and their own language. While most of them were still quite religious (including many eminent Puritans in seventeenth century England), members were open minded, eschewed rigid dogmatism, and accepted (if sometimes reluctantly) the discipline of evidence and logic. Ancient authorities in physics, astronomy, medicine and other areas were still read and paid lip service to, but clearly this community's most fundamental premise was it was acceptable to question the "ancients" and overturn their findings if the evidence called for it, and that they were wrong on many matters. For communications, it depended on the publication of books, newsletters, periodicals, and pamphlets, and an ever-increasing set of epistolary and personal networks (Collins 1998).[4] Indeed, letters were at the very heart of the modus operandi of the Republic of Letters (Ultee 1987). Correspondence clearinghouses or "offices of addresses" were set up, in which private communications were further disseminated.[5]

[3] The earliest mention of the term actually goes back to 1417 (Waquet 1989: 475).

[4] Examples of nodal figures in these epistolary networks were Samuel Hartlib (1600-1662) and Marin Mersenne (1588-1648), both of whom maintained extensive correspondences with the major intellectuals of their age (Webster [1975] 2002: 67-77 and passim; Webster 1970: 8; Collins 1998: 528). Hartlib was known as an "intelligencer," essentially a clearinghouse for new information. In the century following, periodicals increasingly supplemented epistolary networks. More than a century later, François Rozier (1734-1793), publisher of the *Observations sur la Physique, sur l'Histoire Naturelle, et sur les Arts* (widely regarded as the first independent periodical to be concerned wholly with advances in cutting-edge science) assured the American Philosophical Society that "all of Europe will be informed in less than three months" if they sent the new information first to him and that such correspondence would be "indispensable for the progress of science" (McClellan 1979: 444).

[5] These clearing houses had often the purpose of exchanges, where employers could find employees but in other cases they just traded information. One of the first was associated with the French physician Théophraste Renaudot (1586-1653), which was emulated in England by the irrepressible Hartlib, whose office of addresses purported to act as a "Center and Meeting-place of Advices, of Proposalls, of Treaties and of all Manner of Intellectual Rarities" (Webster 1970: 44-47; Jacob 2006: 48).

To be a member of the Republic of Letters was to be connected with others. As Paul Dibon (1978: 46) has noted, "it was the strict duty of each citizen of the *Respublica Litteraria* to establish, maintain, and encourage communication, primarily by personal correspondence or contact." In the 1660s, the first formal organizations embodying the ideals of the community were established. The British Royal Society was a bottom-up organization growing out of the "invisible academy" of Baconians, whereas the French Royal Academy was a government initiative by J-B Colbert. In between those formal organizations and the completely "virtual" epistolary networks there were the many semi-formal manifestations of literary clubs such as the *societé amusante* of Berlin which met every Wednesday at the home of one of its members "with the goal of instructing and diverting themselves at the same time" (Goldgar 1995: 2). Part of it was the "public science" that could be found in coffee houses, taverns, and other informal local venues (Stewart 1992).[6] These institutions soon started to publish scientific periodicals, such as the *Journal des Scavants* and the *Transactions of the Royal Society*, both of which began appearing in 1665 (though neither was at first wholly dedicated to scientific and technological topics). These periodicals were a substitute to printed books and personal correspondence, and created what we call today the scientific paper (McClellan 1979: 425).[7] Even more powerful as a means to disseminate knowledge, technical and other, was the Encyclopedia, a form of knowledge organization and dissemination inspired by Bacon and in some ways the culmination of the European Enlightenment (Headrick 2000; Mokyr 2002: 66-69). By 1780 or so, many of the institutions of the generation and diffusion of science and technology that are still with us were in place in Western Europe. A century and a half may perhaps seem a long time for these institutions to develop, but nowhere else can we discern anything comparable. The Republic of Letters fancied itself an autonomous unit with its own rules and institutions and not subject to the norms and values of the rest of society, rising "above the petty concerns of state and church or so at least they claimed" (Goldgar 1995: 3). Pierre Bayle, the French Huguenot philosopher who lived in

[6] John Houghton (1645-1705), a pharmacist and early writer in the best of the traditions of the Industrial Enlightenment, wrote in 1699 "coffee-houses improve arts, merchandize, and all other knowledge; for here an inquisitive man, that aims at good learning, may get more in an evening than he shall by books in a month" (cited by Cowan 2005: 99).

[7] For more details on the growth of scientific periodicals in the age of Enlightenment, see Mokyr (2005).

exile in Rotterdam and was one of the Republic's early focal points, wrote that "The Common-wealth of learning (Republic of Letters) is a State extremely free... the Empire of Truth and Reason is only acknowledged in it... everybody is both sovereign and under everybody's jurisdiction... the laws of the society have done no Prejudice to the Independency of the State of Nature as [much as to] Error and Ignorance" (Bayle 1734, Vol. II: 389, essay on *Catius*).

The Republic of Letters, then, was decidedly not a construct of modern historians. It was very much an institution of which contemporaries were fully conscious, and they realized its significance. Bayle began publishing his newsletter named *Nouvelles de la République des Lettres* from 1684, printing it in his relatively safe abode in Holland. Bayle said of his "citizens" that "we are all equal, because we are all the children of Apollo" (cited by Dibon 1978: 45). But "all" pertained to an elite that was estimated in Bayle's age to have 1,200 members, and a century later perhaps 12,000 (Brockliss 2002: 8). While the evidentiary base of these estimates can be questioned, there is no doubt that the number of people involved was small. The exact locus of the Republic is a source of some debate. It could be insisted that it existed only as a virtual entity, kept alive by letters and publications that were read by all. But some of it was clearly located in the Royal Society and the French Royal Academy, and the many Continental academies founded in the eighteenth century. Others such as Goodman (1991: 184) see the Parisian Salon as giving the Republic a source of order to the social relations and discourse of the Republic of Letters, a somewhat Francocentric point of view perhaps (Melton 2001: 211).

Unlike the other communities that form the basis of Ostrom's devastating critique of the commons "tragedy," the Republic of Letters was not a local affair and not bound by space. Its operation was based by and large on transcending distance by means of the written or printed word. In fact, it was the very opposite: it was a network of individuals connected by letters, books, pamphlets, and rare but intense personal visits. While there were differences in local institutions and styles, the common denominator of members were their social class, their commitment to what they believed was the growth and dissemination of knowledge, and their Baconian belief that this knowledge may in the end be of service to mankind as a whole. It should be added that their social class over this period was rising, and that men of letters who previously had lived their life with their solitary studies, surrounded by a few colleagues, now found themselves rising in the esteem of their society, invited to fine salons, and expected to dress

well and behave according to the manners and etiquette prescribed by the culture of the elite.[8] To be sure, there was an intellectual underworld of Grub Street hacks immortalized by Robert Darnton, but its impact on the economy — outside that of spiced-up literature — was probably minor.

The ethos of the Republic of Letters conformed to a great extent to Robert Merton's famous characterization of the ethos of science.[9] The most important "rule" of this community was that new knowledge should be placed in the public realm when it was generated. The creator would earn a property right as the rightful discoverer, but such property rights did not include the right to exclude others from using it. Instead, the originator was credited by other members of the community as the original inventor. That this system did not work perfectly goes without saying, as the many priority struggles between scientists attest.[10] The openness was in large part driven by an ideology regarding the moral duties of scientists in their societies. As Descartes noted, "I believed that I could not keep them [my notions concerning physics] concealed without greatly sinning against the law which obliges us to procure... the general good of mankind. For they caused me to see that it is possible to attain knowledge which is very useful in life...and thus render ourselves the master and possessor of nature" (Descartes [1641] 2005: 28). But an economist tends to suspect that beside morality and ideology, there may also have been material motives. The incentives that drove this system, as Paul David (2004b, 2008) has pointed out was through a signaling

[8] In this regard, the Republic of Letters is a good example of what Deirdre McCloskey (2010) has called "Bourgeois Dignity" — the growing value that society placed on features that might be of general utility.

[9] Merton ([1942] 1973) notes four basic characteristics: universalism (knowledge is not specific to a single group); communism (the knowledge is shared by placing it in the public domain and thus becomes a "commons problem"); disinterestedness (researchers and philosophers search for a truth, to be policed and verified by their peers); and organized skepticism (the unwillingness of those in search of knowledge to be constrained by preconceptions).

[10] The earliest priority fights are found in the sixteenth century, such as that between the astronomers Tycho Brahe and Nicolaus Reimers ("Ursus") Baer. Of those, the fight between Leibniz and Newton on the invention of differential calculus is the most famous, but that between Newton and Hooke on optics and between Hooke and Huygens on the invention of the spiral-spring balance in watches are well documented. Equally nasty, if more obscure, is the fight between two Dutch scientists, Jan Swammerdam and Reinier de Graaf on the discovery of a technique to study female reproductive organs around 1665. According to an unsubstantiated account, De Graaf died as a result of the exhaustion caused by the priority dispute.

game, that had patronage jobs as their payoffs, although in some cases publishing a successful book could be remunerative. The economic organization of the Republic of Letters was through signaling. David also notes that it was difficult for outsiders to judge the quality of the members of the community, and the members of the Republic of Letters thus set up mechanisms that sent out signals about the quality of their peers. In other words, the way the system worked was for ambitious scientists to establish a reputation as a high quality person by impressing his teachers and colleagues, who would then recommend him for such patronage jobs. Reputations were transnational. As Daston puts it well, "the avowed foundation of the ...diffuse and often quarrelsome Republic of Letters... was *merit*... and many Enlightenment intellectuals came to believe that foreigners were more trustworthy judges of merit than compatriots" (1991: 379, emphasis added and slightly rearranged).

Patronage could take different forms. Much of it was handed out by the princes and kings of Europe who collected intellectuals at their courts in part just for prestige reasons, but also because their insights could help guide policies and their expertise could come in handy. Galileo was an early case: in 1610 he was appointed as court mathematician and philosopher by the Grand-duke of Florence, and as such he was free to pursue his research (as long as it did not conflict too much with religious doctrine — but that is another story). Leibniz, another intellectual superstar, was hired in 1676 by the Duke of Brunswick-Lüneburg (after 1692 Elector of Hanover), whom he served all his life. Newton was made warden and later master of the English mint in London. Many lesser lights had to struggle for such patronage jobs, but in general the higher one's scientific reputation, the better the chances.

There were of course exceptions to this rule. Many of the scientists in this period did not seek patronage. The interesting case of Isaac Newton shows how reluctant he was to seek patronage. The work that formed the core of the *Principia* was only done at the prompting of Edmond Halley, who repeatedly visited Newton at Cambridge and urged him to complete the work; it was a difficult work that could be read only by a handful of scientists. All the same, it was enough to launch Newton's life into a new orbit of intellectual superstar with one of the best patronage jobs in England. Yet his biography makes it rather clear that this patronage was a by-product, not the original purpose of writing the *Principia*. Some eminent members of the Republic of Letters, such as Robert Boyle, were

wealthy and had no need for patronage — and handed it out themselves.[11] Anthonie van Leeuwenhoek, the eminent microscopist who sent his findings in letters to the Royal Society in London, was a well-to-do Delft merchant, and never seems to have sought more for his work than the satisfaction of his personal curiosity and peer recognition and respect. Not *all* science was open: Newton and Boyle, among others, were rather secretive about their alchemical work, and some notable but eccentric scientists such as the astronomer John Flamsteed and the chemist Henry Cavendish steadfastly refused to release their data until they saw fit. But these were exceptions — the pressures to conform to the new rules ensured widespread compliance.[12]

Reputations were international; the high mobility of European intellectuals was both a cause and a consequence of this mobility. Many of the great minds of the time, including Vesalius, Descartes, Huygens, Bayle, Maupertuis, Diderot, and many others ended up in foreign countries. The implications of the footloose nature of European intellectuals are profound, and I have explored them elsewhere (Mokyr 2006). But what matters here more than anything is the fact that their mobility underscores the disconnectedness of this community from location. This is not to say that these people were devoid of national loyalty or prejudice; the idea that "the sciences are never at war" was more ideal than reality and the tolerance that was preached related to religion, not nationality (Lipkowitz 2010).

The Republic of Letters, on the whole, was committed to Open Science, although the tension between the desirability of making all science accessible in the public realm and the need to protect the natural rights of the inventor and the obvious necessity in providing incentives remained a topic of discussion. The compromise that emerged and that has held up in rough outline to the present day is that *propositional* knowledge (the knowledge of natural phenomena and regularities) would be subject to the rules of open science, whereas *prescriptive* knowledge (technology) could in principle be protected either by secrecy or by

[11] The case of Robert Hooke, a poor but highly talented scientist, who for many years was on Boyle's payroll and part of his household, exemplifies this kind of patronage. It is perhaps no accident that Hooke was one of the scientists who strongly advocated a modified version of open science in which secrecy would be preserved because otherwise those who were "not qualifyed ...will share the benefit" (Eamon 1994: 348).

[12] As Waquet (1989: 493) notes, "The age of secret had passed; to publish became the rule and we know that Mersenne would actually resort to tricks to compel reluctant scholars to become authors. To work for the public interest became henceforth the watchword and the praise of peers had to make room for the public interest [as the main incentive for scientists]."

temporarily excluding others from using it through a patent system (Mokyr 2002). While the precise details of this division varied from place to place and over time, it was an arrangement that worked well enough to propel the West to a technological and scientific domination that lasted three centuries.

Although the Republic of Letters was dependent on beliefs and values, it had little to do with popular culture. It was confined to a small sliver of Europe's "polite society" — educated, literate, polyglot, and cosmopolitan. It was also predominantly male, although at times women did play important roles.[13] The "invisible college" that emerged in the late seventeenth century in full bloom was successful precisely because it was relatively small. Cooperative behavior was encouraged and defectors could be recognized and punished. This kind of equilibrium is more likely to emerge if the "game" is played over and over again, if the participants share an "ethos" of cooperation and know that others do, and if the numbers remained small enough so that opportunistic behavior could be and would be punished. As David (2008: 77) notes, "the norm of cooperative disclosure provided the basis for repeated, reciprocal information transactions that on balance would be conducive to further enhancing the members' reputation." For those reasons, "membership" in the Republic of Letters was limited and not costless. In principle, the Republic of Letters fancied itself to be egalitarian, although this was of course not the case in practice. Yet its hierarchy was ordered quite differently than the rest of society: neither ancestry nor wealth were supposed to count for much: merit, originality, achievement, and erudition were keys to one's place in the hierarchy, and were always formally contestable.

The Republic of Letters believed that useful knowledge should be placed at the disposal of those who might want to use it for technological purposes. It is not surprising that any concrete economic benefits from this ethos were many decades in the future. Technological advances that could be traced directly to scientific insights were still few and far between before 1800, although both the steam engine and chlorine bleaching were notable exceptions. Yet useful knowledge was more than just scientific discoveries. It also involved a large number of publications about engineering and production technology in a bewildering array of fields, which took the form of encyclopedias, compendia, handbooks and dictionaries of various kinds, and planned series of books that purported to cover all fields of

[13] This matter is still in some dispute. For a useful summary, see Melton (2001: 209-11).

economic activity known at the time.[14] Engineering manuals and handbooks in a variety of useful fields were published, translated, pirated, and presumably read at a wider scale than ever before. This was even true in fields where the impact on actual production may seem small before the great advances of the late eighteenth century such as chemistry. P.J. Macquer's *Dictionnaire de Chimie* was published in 1766 and translated into English in 1771 by the chemist James Keir.[15] The publication of books on agriculture and farming manuals by such luminaries as Arthur Young, John Sinclair, Lord Kames, James Hutton, William Marshall and many lesser writers were indicative of the fundamental premise of open science.

Openness meant that new knowledge would be placed in the public realm and was therefore accessible to potential skeptics and critics who tried to reproduce and verify the findings. Thus, openness meant that useful knowledge became more reliable. The reason is that non-specialists contemplating using a specific piece of useful knowledge would know that the self-policing community of specialist experts had vetted it. Knowledge that might be used for practical purposes had been examined and tested by critical experts, and that if it had survived that ordeal, it would be more likely to be correct.[16] Such reliance on peer review could be very treacherous, of course, and a great deal of nonsense and misleading knowledge circulated in this age, nowhere more than in medicine. All the same, there was a built-in mechanism to get it right, and no matter how resistant entrenched incumbents could be, in the end erroneous and dysfunctional paradigms, from phlogiston chemistry to miasmatic medicine were eventually cast aside.

[14] Early examples include Antoine Furetière's *Dictionnaire Universel des Arts et Sciences* (1690), John Harris's *Lexicon Technicum*, which appeared in 1704, and Ephraim Chambers's *Cyclopedia*, first published in 1728, and which went through many editions. The most massive of those efforts in the eighteenth century was probably the eighty volume *Descriptions des Arts et Métiers* (1761-88) produced by the French Académie Royale des Sciences, which included 13,500 pages of text and over 1,800 plates describing virtually every handicraft practiced in France at the time (Cole and Watts 1952: 3).

[15] Macquer, *Dictionary of Chemistry*. Originally printed in 1771, a fifth edition had already been published by 1777, indicating the success of the work.

[16] Bayle ([1697/8] 1734: 389) stressed this important aspect of peer review: "every particular Man has the Right of the Sword and may exercise it without asking leave of those who govern...against Authors who are mistaken...It is true, the Reputation of being a learned man which an author has acquired is sometimes diminished thereby... but if it be done in support of the Cause of Reason and for the interest of the Truth, no Body ought to find fault with it."

A fundamental axiom of the Republic of Letters was that all knowledge was contestable and that there were no sacred cows among scholars. In that regard, the change relative to medieval Europe was still quite dramatic. In the fourteenth century, Oxford University had a rule on the books that every master who deviated from Aristotle's *Organon* would be fined 5 shillings for every case of deviation (Devlin 2000: 58). This rule was still on the books at the time Giordano Bruno visited Oxford (in 1583). But by that time, much of Europe's intellectual community was becoming gradually more heterodox.[17] In the sixteenth century insolently skeptical scholars such as Ramus, Paracelsus, Copernicus, and Giordano Bruno were still courageous exceptions. By the time of Galileo, Beeckman and Gassendi, the old Aristotelian orthodoxy was explicitly questioned and challenged. In 1660, the British Royal Society chose as its motto *in nullius verba* – on no one's word. As a result, much of the work of classical writers in physics, astronomy and medicine was eventually discarded. The Ptolemaic world was unceremoniously dumped in favor of the sounder heliocentric universe. New discoveries about the human body by physicians such as Andreas Vesalius and William Harvey also cast doubt on the canon of medicine such as Galen and Avicenna. But merit, quality, and distinction remained highly subjective and the Republic of Letters created the basic system of peer review that still rules the world of intellectuals. As every academic knows, this is a highly fallible and corrupt system, in which incumbents jealously defend the status quo and in which senior scholars do all they can to protect their human capital from technological obsolescence and undesirable criticism. But it worked far, far better than any alternative that could be dreamed up.

The significance of the Republic of Letters and its subset, the Republic of Science, was not only that it provided the underpinnings of the Scientific Revolution as David has argued persuasively. It serves as illustration of why cultural change in early modern Europe was both faster and moved in a different direction than it did elsewhere. The main source of Europe's success was that it combined political fragmentation with cultural unity and thus had the best of all possible worlds. If it had had one without the other, something would have

[17] Petrus Ramus (1515-1572), a French philosopher and logician made a career out of slaughtering the holiest of holy cows, namely Aristotle's logic. His promotion lecture (1536) was actually entitled "Everything that Aristotle ever taught is wrong." Paracelsus (1493-1541), sometimes known as the "medical Luther," was a notoriously quarrelsome and provocative physician and chemist, who relentlessly attacked the accepted and revered medical doctrines of his time as codified by the classical authors of medicine, whose books he burned in public to show his contempt for the wisdom of the "ancients."

gone wrong. Political fragmentation in a culturally fragmented world like Africa or India would have led to cultural stagnation because no cultural entrepreneur would have been able to cover his fixed cost while catering to a "market" (or audience) of a few thousand people. But in Europe, cultural entrepreneurs from Erasmus and Luther in the early sixteenth century to Newton and Leibniz in the late seventeenth, were famous throughout the Continent.[18] And while most only catered to a small elite, they could access their audiences throughout the Continent and try to persuade scholars in different countries, thus not only selling books but hopefully find a wealthy and powerful patron who would underwrite their careers, protect them from possible reactionary elements, and support an appointment that would permit them to do their scientific work at an acceptable level of comfort. At the same time, the political fragmentation that was coupled to the cultural unification prevented incumbents from effectively suppressing innovators. Effective suppression required close coordination between the conservative powers, and political fragmentation meant that for all practical purposes such coordination was not forthcoming. Political and social pluralism was coupled with a well-coordinated community that "managed" the creation of new knowledge.

Why did the Republic of Letters emerge when it did? There had always been a transnational intellectual community in Europe, but it had been institutionalized in the Christian Church and Latinized culture. As the church was weakened and then divided, it left a vacuum that could be filled by scholars more interested in worldly topics. We must also allow for the growth in the technology and institutions of long distance communication. The effect of the printing press, although perhaps not as immediate as might be imagined by the observer in the twenty-first century accustomed to the meteoric emergence of mass-communications and network technologies, was quite palpable in the mid sixteenth century (Dittmar 2011). The improvement of shipping and road transportation, as well as that of the postal system, were essential for a virtual institution dependent on epistolary networks.[19] David (2008) argues that as aristocratic patrons found assessing the true quality

[18] For a more detailed discussion of the concept of cultural entrepreneurs, see Mokyr (2012)

[19] The improvement of the postal system took place thanks to the organizational abilities of de Tasso family, led by Francisco de Tasso [(1459-1517), later known as Franz von Taxis] and his brothers who established regular postal services in Italy, Germany and the Habsburg lands in the early sixteenth century. Their postal system covered much of the Continent by the middle of the sixteenth century and created one of the most durable business dynasties in history.

of science increasingly difficult as knowledge (especially mathematics) became more complex, they had to depend on the judgment of expert peers to determine who was worthy of patronage. Therefore, every scientist would first and foremost want to impress other scientists and make sure they knew of his work. Yet there can be little doubt that above all that there was a growing realization that the Republic of Letters had a mission, most cogently expressed by Francis Bacon, to generate and disseminate useful knowledge that might one day contribute to material progress, that is to say, economic development.

The exact connection between the Republic of Letters and the Enlightenment has remained the matter of some controversy between scholars. As Brockliss (2002: 8) notes, today's consensus seems to regard the Republic of Letters and the Enlightenment as "distinctive entities" (though he begs to differ). For an economist, however, what mattered most about the Republic of Letters was its functioning as a virtual community that managed a common valuable resource and created the incentives for talented people to create new knowledge and overcome the Arrow dilemma. What mattered most about the Enlightenment was the *Industrial* Enlightenment, the commitment to a belief that the accumulation and dissemination of useful knowledge could and would lead to economic development and material progress. As Jacob and others have shown, the links between natural philosophy on the one hand and engineering, medicine, and agriculture on the other demonstrate the economic impact of this intellectual movement. It consisted of a small sliver of the population, but one that was key to subsequent economic growth. There was much more to the Enlightenment than that, of course, but if we accept that the element that changed Western economies in the late eighteenth and nineteenth centuries was above all technological progress, it is this aspect of the Enlightenment that is most relevant to our story. In that regard, the Republic of Letters and the Enlightenment were two sides of the same phenomenon. It continued straight through the nineteenth century into the modern age. It may well be the most significant example of successful commons management in human history.

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