Carlos Laliena Corbera

The knowledge economy in the preindustrial era

1. Knowledge economy: Towards a definition*

Knowledge economy is a concept that arose in the 1990s as a result of the convergence of different traditions of economic theory around the generic importance of knowledge in the explanation of economic growth.[1] The idea that knowledge is important from this perspective predates this and had different advocates,[2] but the moment in which the group of aspects encompassed in this expression crystallised and was situated at the forefront of theoretical discussions corresponds to this period.[3] At that time it received the enthusiastic promotion from large institutions such as the World Bank and the OECD, in whose studies and planning services it acquired great importance as a general criterion of the recommendations made to member nations in order to strengthen development.[4] The importance conferred

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1 The literature on the notion of the «knowledge economy» is very extensive and, in general, beyond the scope of this paper, so the references cited should be understood as a reading guide. A useful general review can be found in the first part of K. Keong Choong and P. W. Leung (2021).

2 For instance, Fritz Machlup (1980) (which reproduces and amplifies this author's 1962 work on the production of knowledge in the USA) or Daniel Bell (1973, reed. 1999), on the importance of codified knowledge, essential in the transmission of scientific and technological information.

3 Although these are economic theoretical models that are not always compatible and that develop different areas of analysis, the importance of knowledge as a factor of growth appears in the so-called Information Economics, Endogenous Growth Theory and Innovation Systems, which have dominated the economic landscape over the last thirty years.

4 OECD. *The Knowledge-Based Economy* (1996) [https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD%2896%29102&docLanguage=En], where it says: «the OECD economies are increasingly based on knowledge and information. Knowledge is now recognised as the driver of productivity and economic growth, leading to a new focus on the role of information, technology and learning in economic performance» (p. 3). World Bank, *Knowledge for Development* (1998-1999) [https://openknowledge.worldbank.org/bitstream/handle/10986/5981/WDR%201998_99%20-%20English.pdf?sequence=1&isAllowed=y], which states: «economies are built not merely through the accumulation of physical capital and human skills, but on a foundation of information, learning,

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from then to the knowledge factor reached a sufficient level to coin the expression *knowledge society* and to acquire a strongly prescriptive character (Stiglitz and Greenwald 2016).[5] The economic advance, according to these institutions and the circle of influential economists related to them, was the result of applying scientific and technological knowledge to productive systems in order to increase their effectiveness, but also the implementation of forms of mainly education-based learning of individuals, companies, and societies.

From this theoretical and regulatory perspective, knowledge economy is a transversal notion that, in general, involves three complementary aspects: firstly, production and dissemination of technological and scientific knowledge; secondly, cultures and institutions that make the integration of knowledge in the productive system easy or difficult; and finally, human capital development.[6] In this way, the expansion of the knowledge economy results in the production of new goods (and the creation of new industries, in particular in the area of information and communication), advances in business organisation and the productive activity and increases in productivity that accompany these changes (Keong Choong and Leung 2021, Fig. 2).

It deals with a notion that has been said to lack vigour, in theoretical terms, because it is difficult to give it a precise content and because economists find difficulties in explaining and measuring knowledge production or its distribution. In fact, besides having a complicated definition, – what is *knowledge* and what *type of knowledge* is significant for economic activities? –[7] it is a factor that has components

and adaptation. Because knowledge matters, understanding how people and societies adquire and use knowledge – and they sometimes fail to do so – is essential to improving people's lives, especially the lives of the poorest». (p. III). World Bank, *Constructing Knowledge Societies: New Challenges for Tertiary Education* (2002) [https://openknowledge.worldbank.org/bitstream/handle/10986/15224/249730PUB0REPL00Knowledge0Societies.pdf?sequence=5&isAllowed=y], where is affirmed: «the ability of a society to produce, select, adapt, commercialize, and use knowledge is critical for sustained economy growth and improved living standards. Knowledge has become the most important factor in economic development» (p. 7). All documents consulted 22/04/2022.

5 The authors use *learning* to emphasise the operational aspect of acquiring knowledge.

6 Expressed differently, Chen and Dahlman (2005, p. 4). According to these authors, the «four pillars» of the knowledge economy are: an adequate economic incentive and institutional regime for the development of knowledge; educated and efficient workers in the use of knowledge; an effective innovation system, in companies, universities and other organisations; an information infrastructure that facilitates the diffusion of knowledge. As they point out (n. 5) it is not necessary to have high technology or information technology to speak of a knowledge economy: new agricultural techniques or the development of logistic services also work from this perspective of applying knowledge to economic activity.

7 Debates on definition lean towards cognitive and philosophical aspects, with distinctions between «tacit knowledge» and «explicit knowledge» or, as J. Mokyr points out, «propositional knowledge» and «prescriptive knowledge» making up «useful knowledge», although in most theoretical

of a public asset, with aspects related to costs that are complex. In addition, it is susceptible to a wide affordable dissemination that is difficult to control, but, at the same time, it is subject to problems of uneven information and intellectual property rights that restrict general access.[8] Above all, however, it is very difficult to measure the dimension and the characteristics of investment in innovation, the impact of the use of technology and the effects of the different levels of education in the economic advance. Furthermore, the implementation of knowledge leads to increases in productivity that have negative social effects on employment, which is known as «creative destruction» (Stiglitz and Greenwald 2016, 199-232). There exists the added problem of «bad institutions», those that contribute to limiting the use or the dissemination of knowledge (Acemoglu, Johnson and Robinson 2005a, esp. 393-95).[9]

These theoretical problems do not daunt the great economists – who, in fact, have been awarded successive Nobel prizes, the last in 2018 –,[10] who continue having confidence in the virtuality of this concept and, it is sincerely my belief that as historians we should do so as well. With less insistence on the formal and quantitative components, as the sources pose evident obstacles for these issues in relation to the medieval and early modern periods, I am convinced that we can use the intellectual instruments associated with the notion of knowledge economy. Among other aspects, in addition to those already indicated, it is possible to utilise the concepts of innovation, technical know-how, scale effects and indirect effects and of dissemination, productivity, learning and formal education. This perspective contrasts with the idea, absolutely generalised among economists who deal with these issues, who always establish a border between the preindustrial and the industrial period at the level of 1800 which determines a radical change. Before this date, they decreed that the economies were backwards, agricultural, traditional in the most conservative meaning of the word, incapable of evolving and, above all, inadequate to provide decent living standards to the populations. Knowledge of the existing techniques was transmitted from master to apprentice, in a rudimentary form that

literature knowledge is identified with the sum of science and technology: Rooney and Schneider (2005); Mokyr (2008, 17-43).

[8] Romer (1990, 73-75), who uses the criteria of «nonrival» and «partially excludable» for knowledge conceived as technological development: it is a public good that can be used by multiple people or firms simultaneously but is partially excludable for technological or legal reasons (e.g. through patents). On the impact of this approach, Jones (2019).

[9] In the literature on endogenous growth economic theory, knowledge-related problems of power rarely feature. Generally speaking, it is as if knowledge (science, technology, cultures and institutions) were alien to power structures in both contemporary and pre-industrial societies.

[10] Let us point to J. E. Stigliz, G. Akerlof and A. M. Spence, in 2001, and Paul Romer, in 2018, in particular.

made impossible an adequate accumulation and dissemination. Moreover, knowledge behind the technologies that they used was not based on science and experimentation, so it could hardly evolve towards higher levels.

In opposition to this simplistic form of considering growth in the preindustrial era, this Settimana will serve to verify that in the economies prior to the 18th century, a significant increase took place in the application of knowledge in produced goods and development in both technological and organisational innovation, that is to say, of 'useful' knowledge. This also means verifying the effect of the cultures, institutions and power structures on the generation of knowledge, its dissemination and its technological and productive use.

2. Knowledge in the preindustrial era and economic growth

The consolidation of the concept of knowledge economy was integrated within a more general movement, insightfully pointed out ten years ago by Paolo Malanima: the orientation of economic theory, of applied economics and of economic history towards the problem of growth in its different components and, especially, the influence exercised on it by the institutions (2011, 421-22). With this same idea in mind, that of indicating the components of growth, Paulino Iradiel recently requested paying preferential attention to the actual salaries, employment structures, urbanisation rates, agricultural productivity and total production, while he reserved a secondary role for the aspects related to growth and technology, which he considered to be effective on a micro- rather than macroeconomic level (2017, 65-68). However, a historian's typical vision of growth contrasts with the general idea of current economic theorists who, as I have indicated earlier, situate the crucial aspects of economic expansion on innovation and technology – and, therefore, on production and dissemination of knowledge.[11] This choice of the engine of growth pulls a good part of the debate to the field of the quality of technological knowledge of the past. In this way, it situates the historical moment when the take-off ocurred of the mechanisation of textile production, of means of transport and of the use of the new energy sources, which takes place, from this perspective, between 18th and 19th centuries. It is not necessary to emphasise that, in this discussion, the view towards the preindustrial period appears charged with strong pessimism. Citing a recognised author, Karl Gunnar Persson affirms that «the preindustrial era *witnessed a number of ground-breaking innovations* and improvements, but

[11] The great alternative is the explanation, also endogenous, of economic development through the effectiveness of institutions, which starts from the work of North (1990) and North and Thomas (1973) and perhaps finds its highest expression in Acemoglu, Johnson and Robinson (2005b).

they were typically generated by learning by doing. Producers learned that things worked, but had limited understanding of why things worked» (2011, 92). Under these conditions, the possibilities of increasing the technological knowledge and its application were very limited, since it dealt with inventions that were prone to remain at a technological impasse from the beginning, as Joel Mokyr suggests. Even the most important technical findings had limited possibilities of expansion due to the weakness of the «epistemic base», in words of this author (2008, 35).

It so happens that this vision, centred on inventions, inventors, engineers and scholars of learned societies, of the isolated devices and of the specific scientific advances, derives more from a cultural history of technology and, on occasion, from a history of the ideas than from an economic history. It implies great disdain for the material achievements of the period prior to the 18th century, a strongly elitist perception of technological advances – the work of a minority of enlightened entrepreneurs – and a genuine lack of understanding of the forms of knowledge transfer in the preindustrial period.[12] We will return later to this issue, but first it is necessary to do justice to the medieval and early modern craftsmen and engineers.

We can begin with the cultural environment and progress in terms of organisational knowledge. As we know, from the beginning of the 13th century, writing and the use of arithmetic in commercial, legal and administrative activities increased decisively, especially in Mediterranean Europe.[13] At the same time, the communication and information procedures associated with literacy, which do not always involve reading and writing (for example, reading in groups, visual and ritual communication), multiplied. All that we consider formal education expanded and reached numerous groups outside the social elites (Ferrari and Piseri 2013; Grendler 1989; Black 2007; Ulivi 2008; Danna, in this volume). There is no need to stress that this advance was accompanied by important institutional developments in legislation, administration, state accounting and the universities (Harding 2001; Watts 2009; Epurescu-Pascovici 2020; Ridder-Symoens 1994; Grendler 2002). Different aspects that favoured the effectiveness of commercial activities and the reduction of the transaction costs linked to written knowledge, as well as the expansion of the notary culture and the refinement of the merchants' accounting

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[12] This is particularly evident in Mokyr (1993 and 2017) and Burke (2000 and 2012). For Mokyr, the period before 1750 is characterised by the resistance of institutions and social actors against the expansion of knowledge. For a commentary on this aspect, see Bruland (2007). A much broader approach to global technological evolution and implicitly critical of the reductionist view of exclusively European and post-1800 technological innovation: Schäfer and Popplow (2015).

[13] During this period, the influence of the Islamic world was essential, both in the transmission of learned knowledge (mathematical, astronomical, medical) and of certain technologies, such as ceramics. This flow of knowledge was interrupted or very limited in the late middle ages (Glick 1992).

systems gained growing importance in this period (Tognetti, 2018 and 2015; Goldthwaite 2015; Denzel, in this volume).

In the field of architecture and engineering, without a doubt the most advanced field, Stephan Epstein has indicated the enormous importance of the massive construction of cathedrals and other buildings for the creation and dissemination of a sum of technological knowledge that is visible through the considerable homogeneity of these public works. The movement of master builders, groups of masons, carpenters, quarrymen, sculptors and painters, among other experts, assured the possibility that, from one extreme to another of Europe and from the 13th century, if not before, extraordinarily precise practical knowledge was created. Knowledge that, in addition, was profiled with the passing of time and was disseminated thanks to the long duration of these centres of work, which lasted decades. It is possible that the design of these works was relatively simple, based on geometrical rules that operated on the square and the triangle, with proportions derived from very characteristic numerical symbols (Epstein 2009b, 723-24; Guerreau 1992 and 2011), but progress was evident in aspects such as the height and width of the naves or the capacity for distributing the loads, to affirming the stability of the roofs and opening the walls.[14] Moreover, the temples were not the only centres of innovation in engineering. The construction of bridges over the larger European rivers posed challenges of extraordinary magnitude, as shown by the example of the Pont de la Guillotière over the Rhône in Lyon, whose archaeological excavation allows the identification of the succession of operations carried out to erect immense works between the 14th and 18th centuries over a powerful river (Burnouf et al. 1991).

The cathedrals, castles and bridges as centres of the development of applied knowledge (Cavaciocchi 2005) were taken over by another series of areas of technological creativity at the end of the medieval era, especially mining, metalworking linked to the manufacture of firearms, and naval construction. With respect to the first, it is necessary to underscore the existence of technical improvements in the configuration of mines and wells, in the ventilation of galleries and the extraction of minerals. Metalworking benefitted from the transfer of the indirect smelting procedure known as the «forge wallonne» during the 15th century to a large part of northern Europe. High quality iron produced in abundance allowed populating the battlefields and the sieges with bombards, some of them enormous, before the rev-

[14] Bernardi's (2011, 171-87: «L'art et la science») summary is particularly interesting. It is also interesting to note that M. Prak suggests that the construction of great architectural works is an exception to J. Mokyr's distinction between types of knowledge: «the [building] industry achieved impressive accomplishments in practice, without much change in the theoretical foundations of the building craft» (2013, 133). In fact, the same could be said of many other pre-18th century industries.

olution of artillery took place with the appearance of bronze cannons that shot metallic balls. At the same time, ironwork explained in part the transformations experienced by the ships, with metallic reinforcements that consolidated the hulls and permitted an increase in size. Improvements in the design and the manufacture fostered by the creation of large shipyards where knowledge of the techniques and the interchange of technologies were concentrated, especially during the 15th and 16th centuries between the Mediterranean and Atlantic experiences which made possible not only improvements in the galleys that fought in Lepanto, but also the caravels and the large carracks that launched colonial expansion (Benoît 1988; Arribet-Deroin 2015; Ansani, 2017 and in this volume; Unger 1978; 1980, 21-32; 2020; Plouviez 2016).

3. The general frameworks of the development of the knowledge economy in the early modern period

It is not difficult to conclude that the elements inherent to the knowledge economy that I indicated at the beginning – the implementation of new technologies, the formation of cultures favourable to their dissemination and the qualification of craftsmen and engineers – explain in part the relatively rapid economic recovery after the epidemic crises and the European wars of the 14th century.[15] From this scenario, it is necessary to consider six large problems related to the application of knowledge to the European and, later on, colonial production systems that made possible the early modern knowledge economy: the mobility of the merchants and experts, the expansion and integration of markets, the formation of social networks and the strength of craft guilds, the growth of written communication, urbanisation and the involvement of the States. Each one of these aspects, which simultaneously involve techniques, cultures and institutions, are immeasurable for which reason only some indications about them can be made here.

The movement of qualified manpower, which constitutes the first of these aspects, has been a subject of traditional study among historians of the countries, regions and cities receiving the specialised craftsmen and among those who provided this type of immigrants. Every existing late-medieval or early modern trade, manufacture and industry that had some type of technological advance participated in the

[15] An overview, Braunstein 2011. There are alternative explanations, based on the development of institutions favourable to trade and economic expansion: in general, Epstein 2009b; and, for a more concrete analysis, Yun-Casalilla 2019.

migration of workers equipped with the appropriate technical knowledge.[16] It is what occurred with the Italian merchants in Spain (Igual 2007) or in France, in particular in Lyon (Tognetti 2013), countries where they had great influence in the transfer of technical knowledge, even if only with reduced groups.[17] It is important to point out that the resistance of the guilds to integrate the immigrated qualified craftsmen was limited (Franceschi 2019). The mobility of the craftsmen depended considerably on the characteristics of their specialisation. The skilled persons of the textile industry of Ausgburg at the beginning of the 17th century came from a large region of its surrounding area, including other cities. Many of them had prior training and others acquired it in the city. It is interesting to note that the flows were inverted in the 18th century, when the textile activity expanded in rural areas which applied the knowledge acquired in the city, through the creation of guilds, workshops and the application of processes and qualities similar to those existing in the urban area. The overall production suffered, but the benefits of this manufacture were disseminated (Reith 2008, 121-22). Perhaps the most significant example of the knowledge transfer through geographic movements is that of the silk industry. As we know, the diaspora of merchants and craftsmen from Lucca favoured the creation of new production centres of this type of fabric, in particular in Venice (Molà 1994, Franceschi 2012, 84-90), but also in the Iberian Peninsula, especially in Valencia (Navarro 1997). In a later phase, during the 16th and 17th centuries, the movement of silk craftsmen in northern Italy led to first-rate industrial development based on the intensity and dissemination of technological innovation and the transformation of the types of silks (Belfanti 2004).

From the late middle ages, an exceptional extension of the mercantile systems took place, from the geographic and organisational viewpoint as well as of the goods.[18] The incorporation of the colonial worlds to these circuits releases us from trying to give more arguments to the idea of a first globalisation of the exchanges and, with them, of knowledge in all its facets. But even within the confines of Europe, international traffic grew rapidly and the improvements in transportation – especially maritime transport, thanks to the navigational techniques and construction of vessels– were immensely effective. The mercantile knowledge and the banking techniques, especially those related to public credit, reached the entire

[16] General approaches in the framework of a vast literature: Cavaciocchi 1994; Fontaine 1996; Pizzorusso 2007, which situate specialised migrations within broader contexts, in particular temporal movements and the influence of states and institutions.

[17] In addition to technical know-how, the diffusion of a luxury material culture, especially by Italian merchants, was important: Orlandi 2019.

[18] In general, Casado 2011; Epstein 2009a.

European area, far from being concentrated in the Mediterranean world (Guidi Bruscoli 2007). Directly connected to these practices, state-designed governance of currency was increasingly more precise and sophisticated (Lanza 2019). The creation of international trade shows of a financial nature was added to the advance of the multilateral payment forms, with capacity to transfer large sums of money, especially to pay for continental wars (Epstein 2009a, 103-21). Despite these conflicts, it is probable that the transaction costs fell as the European States turned to more efficient fiscal and banking systems (Orlandi 2002; Fortea 2019), accompanied by tangible progress in the field of information. Lastly, the integration of the markets was a consequence of the transformations of the consumer society, which tended to increase and make popular the traded goods (Kowaleski 2006; De Vries 2009).

The importance of the craftsmen's guilds in the dissemination of knowledge in the early modern period has been the subject of long discussions, which have evolved slowly towards a vision less pessimistic than that which presided over traditional historiography. In the words of Epstein and Prak, the guilds were institutions that «(...) helped reduce transaction costs in at least three distinct, significant stages of the industrial process. First, by creating a stable environment, which encouraged craftsmen to invest in training the successor generation. Second, through the coordination of complicated production processes. And finally, in the marketing stage, through the reduction of information asymmetries between producers and customers» (2008, 1-24, quote, 4). The first of these authors has systematised some of these points. He points out that the principal explanation of the universal existence of the guilds in Europe and their prolonged persistence is rooted in the control of the masters over the skilled workers and apprentices, especially in order to guarantee the quality of the apprenticeship and to avoid opportunism from these workers via sanctions. By impeding the movement of apprentices between workshops to improve their remunerations or by reducing the authority of the masters over them, the guilds assured stability in the training process and transfer of technical knowledge that resulted in a homogeneity of the skills of these apprentices. In addition, they also protected the young workers, ensuring their appropriate training, as well as other forms of instruction. Furthermore, Epstein insists that the argument that the guilds opposed technical progress through oversight and the rigidity of the productive procedures is inconsistent. Supervision was limited, technical innovation was difficult to control and there was considerable leeway for the workshops to introduce changes using new techniques without being penalised. Besides, the innovations that saved manpower tended to harm the poor craftsmen, who had less political capacity within the guilds, which explains that the opposition was relatively weak. The State, the cities and the merchants were also able to break down this resistance. Consequently, the guilds were not as impervious to technological change or the dissemination of useful knowledge as has been sustained without sufficient basis (Epstein 2008; Casado 2004). The key factor in the relationship between guilds and useful knowledge is the importance of apprenticeship as the fundamental institution in the transfer of knowledge in the preindustrial era. Intergenerational circulation of knowledge implied somewhat more than the simple development of human capital from the moment it also involved cultural aspects, such as the capacity to produce goods with a quality determined by factors that were not exclusively economic (De Munck 2007).

In fourth place, it is known that, at the end of the middle ages, the production of manuscripts in series had reached certain circles, such as the universities. However, this type of materialization is incomparable with the impact of the printing press which, by itself, brought about a radical change in the volume of information and in the speed of its dissemination during the 16th-18th centuries. During this period, the printed materials were quite diversified, ranging from books to pamphlets or newspapers, creating broad and varied channels for transferring knowledge. Part of these documents were applied to expanding science and even the techniques through treatises and more or less encyclopaedic works (Blair and Fitzgerald 2015). As we will see, all of this was essential for the scientific revolution of the 17th century, but it is more difficult to verify its economic potential. There is no doubt that information in the broad sense was basic for the merchants and for the State governments, which explains the creation of the postal services and archives, but the form in which it influenced the productive systems is less evident. The development of the colonial empires exacerbated the need to have in-depth knowledge about distant realities outside the European experience with the aim of exercising power over them. This creation of knowledge about the colonial world had endless useful applications, such as those related to botany, cartography or navigation systems, but its application to the productive economy is not easy to measure (Brendecke 2012; Carrió Cataldi 2016). However, it can be said that the expansion of general, cultural or tacit knowledge constitutes the ecological means in which the techniques of the early modern period were developed.

Something similar occurred with the last two aspects that we are going to examine. The importance of the cities in the elaboration of knowledge, especially technical knowledge, is unquestionable. The urbanisation rate of early modern societies grew extensively, the regional urban systems grew in density and some European cities expanded until reaching the rank of world metropolises, such as London or

Paris. The cities concentrated the economic, cultural and political institutions, in addition to becoming the basic infrastructure of the national States. The commercial networks unified the urban systems and connected them with countries outside of Europe in a phase of intense globalisation. The economic growth was increasingly the result of production of goods and merchandise in the cities,[19] in such a way that the proximity between the workshops facilitated the reduction of costs, collaboration between the craftsmen, dissemination of knowledge and transfer through apprenticeship. The city strengthened the development of human capital through formal and informal educational institutions, such as schools, orphanages and asylums for children and poor workers; the city-based guilds fostered the teaching of the techniques of the corresponding crafts. The immigrants that moved between cities transferred with them their technical resources and initiatives, without the restrictions that they occasionally came up against being sufficient to avoid this transfer. The cities granted privileges and monopolies that stimulated the success of some industries, especially those related to luxury. Hybridisation, innovation and creativity were patrimony of some cities that accumulated innumerable objects that carried with them the technical information on how they had been produced. And the cities were subjected to continuous physical renovation –spaces, buildings, churches, palaces and other headquarters of power– which led to intense circulation of knowledge (Davids and de Munck 2014; de Munck and Romano 2020; Klein and Spary 2010).

Lastly, we must underscore the effectiveness of the State in the promotion of knowledge. As occurred with cities or communication, the State is in turn a participant in the drive for innovation and the institutional context that contributes to expanding it. The European States, regardless of their form and dimensions, generated knowledge. Their bureaucracies gathered information, as we have seen, with the aim of intervening in the social body. The State accumulated power and the power was expressed in multiple forms at the heart of the economy and knowledge. Perhaps the most evident is the granting of patents to the inventors, a procedure with medieval precedents that the Venetian State organised in the most perfect way at the end of the 15th century (Belfanti 2004 and 2006). During the early modern centuries, the idea of granting benefits in the form of monetary compensation or temporary exclusivity in the enjoyment of the income derived from an invention reached all the States and many European cities. Among them, Colbert's France stands out, whose bureaucracy made an enormous effort to control inven-

[19] This urban leadership does not contradict the considerable importance of rural protoindustries in this period (DuPlessis 2001: 261-347; Marfany 2012).

tions, both through administrative registration and through verification of the effectiveness of the inventions or technical innovations by men of science. Not only was it done in a centralised manner – in Paris – but also in the provinces, where the mayors promoted experimentation and the technological change on the local level (Hilaire-Pérez 2000, 39-142). In theory, the patents restricted the expansion of knowledge by establishing monopolies on the discovered techniques, but in this period imitation and hybridisation left little margin for preserving technological secrets and this type of awards was hardly a deterrent to the dissemination of knowledge (Degrassi and Franceschi 2018).

The creation of the national schools of engineers at the end of the early modern period was the culmination of a mobilisation of experts in weaponry and fortifications that was massively recruited by the States. The publication and translation of treatises on these subjects is the best possible expression of this circulation of specific knowledge based on mathematics and geometry for the construction of forts, their siege and resources, especially artillery, necessary for defence and attack (Spicq and Virol 2016; Virol 2016). These treatises constituted the theory, which can be referred to as codified knowledge, but the practice is equally evident, in view of the enormous quantity of urban fortifications and border forts in the Low Countries, France and the Empire, not to mention those erected in the Spanish colonies. The States were deeply involved in the application of this architectonic knowledge and the architects and engineers could learn simply from observation and imitation of the existing constructions. Any reservation on the exceptional economic dimension of this intense utilisation of useful knowledge is misplaced (Parker 1996).

The large fortification systems that proliferated throughout the continent are only one part of the investment in military technology. From the Hundred Years War to the Napoleonic Wars, the military conflicts were incessant and the European States mobilised human resources, economic means, military specialists and, above all, weapons technologies. Firearms and war ships were the most important of these technologies, which were subjected to continuous improvements through minor but accumulative technical changes. The result was not only greater effectiveness of these weapons, but also a dramatic reduction in costs and an increase in their production. These advances, furthermore, were the work of different types of craftsmen who combined their skills in order to increase the efficiency of the weaponry. It is not really necessary to say that none of these experiences in the fabrication of weapons were secret or could be kept out of a very rapid circulation of knowledge.

The European States, or perhaps better stated, the kings of the early modern world were surrounded by splendour, pomp and, among the most spectacular manifestations, the palaces stand out, not only for their extraordinary outlays for their construction, but also for the expenses in their decoration. To cite just one example, the Buen Retiro palace of Madrid cost around three or four million ducats, equivalent to 3-4% of all the expenses of a monarchy with world interests during the decade of 1630-1640. From all that, an important part was allotted to furniture, tapestry, paintings and works of art, clocks and, in general, objects of an exquisite manufacture (Brown and Elliott 1981, 99-109). Demand at this level and quality stimulated the production of ostentatious consumer goods and fostered innovation in this type of industries, which was applied later to productions of a lower economic level and greater popular scope, as occurred with the clocks (Landes 2007). In addition, royal courts were converted into centres of attraction of technical innovation, in particular, Versailles, where the investors were welcomed with a patronage that extended widely from the royalty to the aristocratic elites (Hilaire-Pérez 2000, 226-32).

In conclusion, from the viewpoint of the knowledge economy during the late middle ages and early Modern period, it is necessary to insist that it deals with a period in which there was a continuous circulation of technological knowledge that led to a hybridisation of knowledge, a creative imitation or adaptation of techniques, and that this dynamic had a global dimension. It is increasingly more evident that the European advances explicitly or tacitly appropriated knowledge coming from the Asian and colonial worlds. Part of this knowledge was included in the objects, in the imported material culture that posed a technical and quality challenge for the European craftsmen. But this capture also resulted in research, in scholarly work, travellers, merchants, military personnel and public officials who discovered materials, processes, designs and production systems distinct from the European ones, as occurred with the cotton fabrics from India and their influence in England (Berg 2004 and 2013). This circulation intensified within Europe from the late middle ages due to the succession of large regions where the accumulation of technological changes in specific industries occurred. Northern Italy and its engineers of the 15th and 16th centuries gave way to Central Europe's development of steel and mining and this in turn to the Low Countries' light textiles and luxury productions, and from there to Colbert's France, and to the textile manufacturing of 18th century England.[20]

[20] This succession is frequently cited; among others see Epstein 2009b, 717-18.

Secondly, the development of new global markets, of new cultural expectations and of new consumer practices created a demand for luxury and semi-luxury products, such as, to cite some examples, silk, enamelled ceramics and porcelain, glass, and oil paintings. The history of each of these products illustrates the complexity of technological innovation, knowledge transfer and the local adaptations in the framework of already existing technical cultures. It is evident that it dealt with relative innovations – since silk, ceramics, glass and paintings existed previously – and that their dissemination was done through both traditional and innovative channels, in particular, the mobility of the craftsmen and the painters, but also through the development of retail stores for this products (Blondé, Stabel, Stobart, Van Damme, 2006). However, the introduced improvements gradually reduced their price and popularised them, created economies of scale and increased their marketing, as occurred with the Dutch genre paintings of the 17th century, converted into an everyday object in the bourgeois homes of the Netherlands or the silk fabrics that enormously increased their clientele (Molà, Mueller and Zanier 2000; Goldthwaite 1989; Finlay 2010; Maitte 2014; Nuttall 2004; Bozal 2002). The late middle ages and early modern knowledge economy is integrated deeply in the formation of a preindustrial consumer society.

Finally, it is important to consider that the innovations and dissemination of technical knowledge were frequently presented as «technological packages» that included different interrelated components. A classic example is printing, which required fabricating new inks different from the medieval ones and it required improving the production of paper (Johns 2010; Cavaciocchi 1992). There was another type of integration, such as that which united ships and cannons, as described hitherto by Carlo Cipolla (1965). This integration imposed significant technological changes on both fields, shipbuilding and the manufacturing of cannons. In reality, nearly all the productive activities coordinated different elements that were, up to a certain point, independent, but the sum of all of them noticeably increased the economic and cultural impact – or, such as the example of the cannons and the sailing ships, the power – and, therefore, the result can be classified as technological innovation.

4. Knowledge transfer in the preindustrial era

In the 17th and 18th centuries, a better and cheaper access to knowledge thanks to printing led to the gradual transformation of the oral tradition in the transfer of technological knowledge to a written and also progressively scientific form, of which the publication of numerous encyclopaedias and technical treatises has been a good demonstration. Joel Mokyr has proposed with some success the concept of «Industrial Enlightenment» for this movement that affects the European intellectual elite in the second half of the 18th century (2008, 45-89 and 2017). An elite that was united virtually in a «Republic of Letters», based on the exchange of information among scholars in order to register and codify the existing technology, explain the functioning of the different techniques that comprised it and increase its effectiveness through a growing development of inventions and machinism. In accordance with this approach, the Industrial Enlightenment was at the base of the Industrial Revolution[21] by decisively transforming the prior useful knowledge, expanding its epistemic bases so that it was no longer based on trial and error or in the recipes transmitted from master to apprentice.

The arguments of this author have been partly completed and also partly revised by Jan Luiten van Zanden (2009), who situated the origin of the knowledge economy that took place in the Industrial Revolution in the development of efficient institutions in the medieval period that favoured a growing accumulation of comparable knowledge through the increase of the production of fundamental goods in this regard, such as books. In second place, he indicated that this progress continued during the 16th to 18th centuries and that it is possible to measure it thanks to the evolution of the remuneration of specialised work (*skill premium*). The reduction of the differential between the salaries of specialised workers and those not specialised indicates high levels of human capital development and, consequently, it is an important factor in detecting economic growth. The drop in this differential during the late middle ages and its later stabilisation during the early modern period suggested that the training mechanisms of the European employees worked. The increase in production and the drop in the price of books served this author to verify the high educational level – equivalent to literacy– of the human capital, especially in northern Europe – Great Britain and the Netherlands.[22] With these arguments, Jan Luiten van Zanden justified the progress in the qualification of human capital. The comparisons with the Mediterranean and Asian regions per-

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21 «By the middle of eighteenth century the attitudes toward technology-driven material progress had changed dramatically, a phenomenon I have called in early work the Industrial Enlightenment and wich was a foundation of Industrial Revolution» (Mokyr 2017, 142). On the «Republic of Letters», open science and the feeling of belonging to a community of European intellectuals, Mokyr 2017, 180-224.

22 Classic studies by Carlo Cipolla (on literacy) (1970), Alfred W. Crosby (on quantification) (1998) and Federigo Melis (on commercial accounting) (1991) have shown the cultural background against which human capital formation evolved since the late middle ages. As Jan Luiten van Zanden has put it, «the hypothesis is that consistent with endogenous growth theory (and unified growth theory), increased knowledge accumulation and increased investment in human capital through education preceded the emergence of modern economic growth» (2009, 8).

mitted him to underscore the advantage of northern Europe and explain the geographical-time location of the decisive turn that Mokyr proposed at around 1750.

This great narrative has been criticised as being Eurocentric and even Anglocentric and for underestimating the importance of the forms of knowledge transfer and their technological and economic dimension of the preindustrial era (Carnino, Hilaire-Pérez and Kobiljsky 2016; Hilaire-Pérez and Verna 2009). In this respect, S. Epstein and M. Prak have shown that the transfer of technical knowledge through apprenticeship was a very effective mechanism, relatively cheap and adaptable, which explains its lasting nearly a millennium. [23] It served to transfer some technical knowledge and manual expertise whose acquisition took years and that was difficult to codify or teach in any other way. In particular, the attempts to compile treatises in the early modern period suggested that its authors omitted a very important part of the information from the text because they relied on the result of the skills of the craftsmen. The same occurred with the patents, whose history runs all through the early modern era, which did not guarantee the exclusivity of the protected procedures. In this context, the craftsmen's guilds ensured the quality of apprenticeship and regulated the admission of immigrants who contributed new knowledge and new products. Except in fields in which chemistry was basic, reverse engineering was almost always possible and technical secrets difficult to keep. That explains the institutionalisation of the master-apprentice model and also the wide cooperation among engineers, architects and qualified craftsmen (for instance, Ibáñez and Zaragozá 2017). The advantages of open knowledge fully exceeded the possibilities of obtaining benefits by hiding findings.[24] In addition, there always existed sites of labour concentration that fostered this horizontal dissemination, such as the large architectonic works, the shipyards or the metalworking centres. A knowledge transfer was also derived from the migration of specialised craftsmen, as we have indicated. Their mobility made it possible for them to find places where their technical skill gave them a temporary competitive advantage over the local workshops, before their knowledge was disseminated and the advantage disappeared. These migrations were encouraged by the States and cities that favoured the incorporation of specialists in fields with high demand, from silk-making to weaponry. Others, such as that of the painters or architects, depended on a semi-public, but always intense, demand, such as that which affected the German master builders or architects in the

[23] A much more critical view of the effectiveness of guilds in human capital formation and innovation in Ogilvie 2019: 354-510.

[24] This idea is implicit in the notion of «disegno rinascimentale» as a fluid circulation of knowledge about the characteristics of luxury products in fifteenth- and sixteenth-century Florence (Nigro, 2020).

15th century. In summary and in the words of Stephan Epstein, «notwithstanding the absence of much written evidence, evidence from technical practice suggests that pre-modern non-scientific technical knowledge expressed significant degrees of abstraction, experimentation and cumulation.» (Epstein 2009a 743; Epstein and Prak 2008).

Liliane Hilaire-Pérez (2007) reached the same conclusion, defending the artisan culture in the transformations that took place in the 18th century. The capacity of the craftsmen was not only a sum of specialised skills, but rather it included sufficient intellectual resources to develop new products and modify them according to consumer demand. Furthermore, the craftsmen practised forms of open knowledge and competed in the markets, which signified a marketing of knowledge. In the Age of Enlightenment technical schools began to operate, many craftsmen acquired transversal skills and the State as well as the guilds and municipal governments awarded and financed technological inventiveness, as shown by the well-known example of silk-making of Lyon. Hilaire-Pérez added that the complexity of the manufactured objects grew considerably and created new forms of organisation, cooperation and division of labour: the material culture favoured the open knowledge of the techniques. Lastly, this knowledge was disseminated through public demonstrations such as shows and fairs above all, thanks to printing. Both dissemination processes extended beyond the sphere of the craftsmen and permeated the consumers who acquired wide knowledge of the technical conditions of producing goods.

In some respects, the consensus on the idea that in the 17th century a "Scientific Revolution" took place at a European level that set the bases for the expansion of science in the following century can be considered as a criticism of the unique and revolutionary character of the Industrial Enlightenment and, in general, of the scientific development linked exclusively to the Late Enlightenment. This intellectual innovation process was fed by the printing works, the multiplication of scientific societies, the intense communication among cultured persons and the influence of the first globalisation. This Revolution relegated to a discrete obscurity the classic and medieval tradition on nature and it produced decisive changes in different disciplines, from astronomy to medicine, which could not be separated from the general preindustrial knowledge expansion movement that we have described (Burke 2000, 38-44).

5. Productivity, risk reduction and human capital formation in medieval and early modern centuries

As occurred in many aspects of the economies of pre-statistical societies, it is difficult if not impossible to quantitatively measure the effects of the application of knowledge in the production of goods. The effectiveness of a new technique or device is rarely measurable, nor is the qualification of the workers and their productivity. This is not rare, among other reasons – as we indicated at the beginning – because the characteristics of knowledge even at present make it very difficult to measure the benefits of the educational policies on the increase of productivity in a specific country or to separate this factor from others that coincide in this growth. Outwardly, the results of the application of new technologies or specific inventions are more evident, but even here it is not easy to evaluate the part of the productivity that depends on innovation and that which comes from the training of the workers that put it in use. Without extending these considerations, it is obvious that some medieval and early modern inventions revolutionised productivity in certain industries, such as the spinning wheel in silk production, especially when hydraulic energy is applied to it (Crippa 2000, 16-22). In other cases, new products were created whose importance is difficult to exaggerate. Therefore, to cite one among an endless number, the printing press, besides launching onto the markets large quantities of books, made possible the appearance of a peculiar item in sixteenth-century Spain, the *Bull of the Crusade* or indulgence, a paper document that offered a waiver of sins to whoever bought them, for themselves or for their deceased family members, and whose sale was divided between the pope and the crown. Between 1509 and 1513, the printing presses of three monasteries of Castilla manufactured a minimum of six and a half million of these papers that produced income for the Spanish monarchy during these four years equivalent to a third of its budget (Ladero 2019). The possibility of printing the bulls transformed a rare and unusual item, the papal indulgence, into an inexpensive product –if you can refer to alms in this way– and accessible to the entire population, which was put in contact with a written text loaded with symbolic content.

Some sectors of the economy are more prone than other to verifying these advances in productivity. In particular, the textile industries show the complexity of the adaptations of the different types of fabric to the expectation of demand, producing a considerable variety of mixed products of cotton, silk, linen and wool in very diverse proportions but, in any case, light and capable of supporting dyes and printing that satisfied the consumers. The European consumers were particularly attracted by the cotton fabrics coming from India – which could only be imitated with fabrics partially made with cotton, since this raw material was expensive in Europe, as were the salary costs –, but also the participants in an African 'market' organised around the slave trade. John Styles (2022) has shown the effect of this growing demand on the ingenious combinations of fibres hidden under the general term of "cotton" which come from a hybridisation model characteristic of this type of industries from the medieval period, but also the influence exercised by consumer interest in velvet, stockings, muslins and calicos in the creativity of the British inventors of the second half of the 18th century, in turn supported by slave cotton.

The Florentine case, studied by Francesco Ammannati and other authors, is interesting in this context, since it shows the failure of an industry clinging to a traditional productive model that had its days of splendour in the late middle ages, but which lost competitiveness from the end of the 15th century and shunned introducing innovations that could have improved it. The decline in the production of wool cloths in Florence has long been known as well as some of the factors that provoked it. The increase in the price of quality wool and the reduction of the supplies were important aspects, as well as the defence of a solid currency that impeded reducing the prices. But the main weaknesses, as this author pointed out, were the rather inefficient organisation of the companies, the very low productivity of labour and no innovation, both in the productive systems and in the types of fabrics offered to the consumers. The elite group of textile businessmen refused to adapt to a demand that wanted lighter wool cloths and that favoured silk, linen and cotton in the products of different qualities. The solution of reducing the salaries of the Florentine workers was not sufficient to mitigate the absence of the elements typical of the knowledge economy: technical innovation, organisational culture, development of human capital and institutions that promoted the application of knowledge (Ammannati 2020; Malanima 1982). Surely other manufactures could be entrenched in their traditional techniques, and it is also probable that in many European regions the persistence of rural industries was sufficient to cover a good part of the demand, but this example highlights that the evolution fostered by knowledge was inevitable in many other production domains.

Similarly, the cultural formation of medieval and early modern workers, or, to put it another way, the characteristics of this aspect of human capital, its measurement and influence, is a debated issue. If we leave aside the aspects included in master-apprentice learning – controlled by corporations to a greater or lesser extent – literacy and years of schooling are usually the factors that justify the increase or decrease in the general training of workers in the pre-industrial era. This approach is based on the premise that a higher cultural level predisposed worker to make better use of technical resources, to be more productive and efficient, and to better transmit their knowledge to their peers and apprentices. From this point of view, there is a growing consensus among historians about the relatively high rate of schooling of both city dwellers and peasants before the 18th century, including the medieval period, a rate that declined during the first phase of industrialisation.[25] We should probably retain the idea that, in general terms, the printing revolution and schooling promoted the further upskilling of European workers.

In this regard, this set of economic factors that we encapsulate in the «knowledge economy» formula promoted the resilience of the European medieval and early modern societies towards the severe demographic, economic and military crises they had to face from the 14th to 17th centuries. Growth – unequal and very different according to the large regional areas of Europe – of this period was based on innovation and technology, basic components of the endogenous growth through the increase in productivity and the decrease in risks. It was also a consequence of the renewal of the institutions and the decrease in transaction costs, as suggested by other historians, which promoted the development of trade worldwide. In this level of abstraction, these large theoretical models have multiple aspects that are difficult to separate in reality, as is evident. But productivity and risk are not minor problems and it will be sufficient to indicate that the Third Settimana Datini was dedicated fifty years ago to the *Produttività e tecnologie*, a precise indicator that economic historians continue to be concerned by these crucial issues. It is appropriate to point out, however, that in the congress proceedings of the cited Settimana, none of the authors used the concept of "knowledge" and they focused on agricultural yields, technological devices and organisational efficiency, but they did not ask themselves about the conditions of creation, accumulation and transfer of useful knowledge.[26] This observation is a measure of the need to respond to the questions that we have proposed on the cultural processes of dissemination of knowledge, the social and institutional networks and the characteristics of the development of human capital in the preindustrial era, essential in order to verify two things: the first, that all of that served to promote economic growth processes of diverse nature during the preindustrial era, and, the second, that the scientific and

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[25] In addition to the references already indicated, Derville 1984; De Pleijt 2018. For the development of arithmetic knowledge in medieval period and 16th century, Danna, 2022. For books production and human capital formation, van Zanden 2009, 69-91 and 178-201. It is interesting too Rideau-Kikuchi 2022.

[26] Mariotti 1981. The Settimana took place ten years earlier, in April 1971. The secondary role of knowledge, innovation and technology is very visible in Hermann van der Wee's synthesis at the beginning of this volume (1981, 9-16).

technical transformations that began to take shape around 1800 are sustained on the knowledge economy that dates back to the medieval period.

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