Why did the Industrial Revolution Start in Britain?[†]

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Abstract

The main goal of this paper is to provide an integrated overview of the literature devoted to identifying the causes of the British industrial revolution. Why did the industrial revolution, a fascinating and multifaceted event which brought about modern economic growth, occur in eighteenth-century Britain? This question has animated a lot of discussions among scholars and is still nowadays heatedly debated in the literature. This debate is reflected in the large spectrum of theories which aim at explaining the true origins of the British industrialization. The paper first sheds light on a rising debate concerning the evolution of British incomes per capita before the British industrial revolution and the "Great Divergence". The paper then investigates the proposed causes of the British industrialization, aggregating them into seven broad categories, i.e. (1) geography and natural resources, (2) demography, (3) agricultural progress, (4) demand-side factors, (5) trade and empire, (6) institutional and political factors, (7) science, technology, and human capital.

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1. Introduction

The industrial revolution, which started in Britain before sweeping through Europe and the USA, is traditionally viewed as the deepest mutation ever known to have affected men since Neolithic times. As Cipolla (1975:7) contended: "*Between 1780 and 1850, in less than three generations, a far-reaching revolution, without precedent in the history of Mankind, changed the face of England. From then on, the world was no longer the same. Historians have often used and abused the word revolution to mean a radical change, but no revolution has been as dramatically revolutionary as the Industrial Revolution, except perhaps the Neolithic Revolution*"[1]. The industrial revolution shaped the face of new industrial and economically successful societies by modifying their social and economic structures and destabilizing all established hierarchies. It eventually influenced every aspect of people's daily life. Thanks to the introduction of new high-impact inventions into the world of production, which emerged in a changing intellectual environment, the human power of production was released in a spectacular way. The industrial revolution indeed witnessed an explosion of the production of various manufactured goods such as textile items and metal products. Equipped with new technologies, the industrializing economies were henceforth able to produce an increasingly larger quantity of products to answer the basic needs of a growing population characterized by new consumption habits and aspirations. The industrial growth was accompanied by the large-scale development of the transport infrastructure (roads, canals and railroads) that contributed to expanding the markets and speeding up the commercial flows. The factory system, a new form of labor organization, developed progressively and started to regulate people's life as never before. Combined with the modernization of agriculture, the industrial revolution moreover accelerated the urbanization process in the industrializing countries. It also witnessed the emergence of a new social structure characterized by the consecration of a more-and-more powerful and influential bourgeoisie, animated by a rising capitalist spirit, and the birth of a new working class sometimes called "the proletariat". All these changes helped to transform the societies which successfully undertook an industrial revolution and move their economy on a new growth trajectory. The industrial revolution is to some extent the birth certificate of the modern world.

According to traditional historiography, the industrial revolution first started in Britain in the second half of the 18th century. The *annus mirabilis* year 1769, as Cardwell (1972) has called it, during which James Watt and Richard Arkwright patented respectively the separate condenser for the steam engine and the water frame, has often been considered as the symbolic starting point of the British industrialization. The industrial revolution then swept through Europe - first in Belgium and France - and the USA, before reaching Japan and Russia

[1] Cited in Fremdling (1996)

by the end of the 19th century. In reality, it's particularly difficult to date precisely when the industrial revolution began in one specific country. Even though historians like resorting to symbols to date the periods of history, the beginning of the industrial revolution, contrary to some historical events like the world wars, cannot seriously be assimilated to one specific year. From an economic point of view, there seems to be a consensus on the idea that the industrial revolution corresponds to an increase in the rates of efficiency growth. According to Clark (2007a:139)'s estimates, the average rate of efficiency growth through technological change in the world economy was close to 0 before 1760. Between 1760 and 1860, the average rate of efficiency growth in England rose to 0.5% per year (Clark, 2010a: table 34), a rate still modest by later standards - i.e. compared to the rates of total factor productivity (TFP) growth achieved by modern successful economies located at or near the technological frontier in the 20th century - but remarkable given its sustained character. In Clark (2014)'s terms, this upsurge in efficiency advance was a singularity, a unique break in world economic history, marking the onset of what Huntington (1996) has called the "Great Divergence" between the successful Western countries and the rest of the world. As Clark (2014:219) defended: "*Before the Industrial Revolution we find no sign of any equivalent efficiency advances. This is true globally all the way from 10,000 BC to 1800".* As shown in table 1, the textile industry, which saw the emergence of many technological inventions, contributed 43% of all measured productivity advance in England between 1780 and 1860. Transport, especially with the development of the railway, and agriculture were respectively the second and third biggest source of efficiency advance. Although innovative, and crucially present in most books of the industrial revolution, the sectors of coal, iron and steel yet accounted for only little of the estimated productivity growth.

Table 1: Sources of Industrial Revolution Efficiency Advance in England, 1780s-1860s

Sector	Efficiency Growth Rate (%)	Contribution to National Efficiency Growth Rate (% per year)
All Textiles	2.3	0.25
Iron and Steel	1.8	0.02
Coal Mining	0.2	0.00
Transport	1.5	0.12
Agriculture	0.4	0.11
Identified Advance		0.49
Whole Economy		0.58

Source: Clark, 2007a: table 12.1

Why did the industrial revolution happen? Formulated in such a way, the question is pretty unanswerable. That's why researchers have increasingly dealt with more focused versions of this question (Mokyr, 1999). Examples are: Why did the industrial revolution start in Britain and not elsewhere, for instance in the wealthy Dutch Republic or in France? Why did the British industrial revolution eventually break out in the late 18th century and not before? Why was the industrial revolution a European (or a North Atlantic) phenomenon? Why did the industrial revolution take place in Northwest Europe and not in East Asia, two regions that seemingly were equally advanced when going into the 18th century? Is it possible to define some necessary preconditions for the industrialization to have occurred? If these questions share similar arguments, they obviously also call for specific answers. In particular, all the economically successful countries did not follow the same industrialization path. Each national experience was unique. The uniqueness of the British experience came partly from its precocity. As it was the first country to undergo an industrial revolution, Britain presents in some way the "purest" case of rapid industrialization.

In this paper, we carry out an economic survey on the literature devoted to identifying the causes of the British industrialization. What are the main factors which have been advanced to explain why Britain was the first country to experience a successful industrial revolution that eventually turned into modern economic growth, thus writing the first lines of a new page in the world economic history book? If some of these factors are specific to Britain's economy and society and rather help to understand why Britain came to take the lead in the industrial revolution, others can be directly extended to the European level and then help to understand why the industrial revolution was in fine a European (North Atlantic) event. This economic survey, which aims at updating and completing Mokyr (1999)'s previous survey, also spends time emphasizing the main points of criticism that have been directed to the proposed causes of the British industrial revolution. As this survey is not part of a new book coming up with a new explanation of the British industrial revolution, it deliberately has the feature of being neutral, thus giving the same amount of credit to each theory. In light of the different arguments and criticisms, the reader is invited to forge his own interpretation of the British industrial revolution. A major challenge facing the literature on the causes of the British and European industrialization is the lack of reliable and generally recognized data on the period under investigation. Most data, especially economic data, are based on estimates and assumptions which are far fro*m* being consensual. Conflictual estimates thus make the debate sometimes hard to follow, at times giving credit to one specific theory and at times dismissing it. To keep things as clear as possible, we choose, as part of this survey, not to go too deeply into the statistical debate, although we will provide data supporting the different theories with parsimony. The paper is organized as follows. Section 2 sheds light on a new rising debate on the evolution of the British and European economy in the centuries before the industrial revolution, and on the economic forced behind this evolution. Was Britain trapped in Malthusian dynamics or already launched on a progressive path towards modern

growth? Section 3 constitutes the core of this paper. It provides and develops an important but non exhaustive list of the main causes of the British industrial revolution proposed in the literature. These causes are aggregated into seven broad categories: geography and natural resources; demography; agricultural progress; demand-side factors; trade and empire; institutional and political factors; science, technology, and human capital[2]. A final section gives some concluding thoughts and remarks.

2. Before the industrial revolution

There is a rising debate in the literature concerning the evolution of the British income per capita and real wages prior to the industrial revolution. While the industrial revolution has long been seen as the key break in world economic history, characterizing the passage from Malthusian societies to modern ones, as well as the appearance of what Huntington (1996) called a "Great Divergence" between the successful Western countries and the rest of the world, a new view has recently emerged to support the idea of a "Little Divergence" taking place during the centuries preceding the industrial revolution. Clark (2011, 2012a) makes reference to these competing views as a new debate between "Malthus" and the "revolt of the early modernists[3]" (Nuvolari and Ricci, 2013). The Malthusian view, notably adhered to by the California School world historians, considers that all economies were trapped in Malthusian dynamics before the industrial revolution. Income per capita fluctuated around a subsistence level - defined as the level of income at which birth and death rates are equal (Nuvolari and Ricci, 2013) -, but exhibited almost no upward trend, an evolution Persson (2008) describes as "the Malthus delusion". Thus, Clark (2007a, 2010a, 2012 and 2013)[4] has repeatedly affirmed that the English income per capita in 1800 was not higher on average than in most of its history since 1200, and even more surprisingly since as far back as the hunter-gatherer era. In line with the Malthusian view, many scholars have defended that Europe, compared with other civilizations, did not enjoy any economic advantage in terms of living standards and income per capita when breaking into the 18th century. In parallel, a lot of studies have shown that other parts of the world, especially East Asia, seemingly shared a number of characteristics with Britain and Europe's economy and society in the 17th and 18th centuries, like long-distance trade, secure contracts and property rights, or consumption habits, and were more advanced in certain areas (see e.g. Wong, 1997; Li, 1998; Pomeranz 2000; Vries, 2003; Parthasarathi, 2011; Goldstone, 2002, 2008 and 2012) (Goldstone, 2015). The alternative view, strongly defended by the "early modernists", contends that Europe was already progressive, both intellectually and technically, since the Middle Age, or at least

[2] I am partly indebted to Mokyr (1999) for the categorization of the causes of the British industrial revolution.
[3] The term "early modernists" was first used by de Vries (1994) to describe the challenging view that Europe was not stagnating in the preindustrial period.
[4] See also Clark et al. (2010, 2012).

the Renaissance, making significant advances in areas such as architecture, manufacturing, exploration, shipbuilding, navigation, agriculture and science, a situation often described as the "Rise of the West" which would accordingly have contrasted with the stagnation of the other civilizations (Goldstone, 2015). From a pure macroeconomic point of view, the early modernists have detected a small but steady acceleration of growth in Northwest Europe, at least in two countries, namely England and the Netherlands, before the industrial revolution (see e.g. Wrigley, 1985; van Zanden, 2002; Broadberry and Bishnupriya, 2006; Allen, 2008a; de Vries, 2008; Maddison, 2008; Persson, 2008; van Zanden and van Leeuwen, 2011, 2012; Broadberry et al., 2011, 2015; Nuvolari and Ricci, 2013; Broadberry, 2014; Broadberry, Guan and Li, 2014; Bolt and Van Zanden, 2014; Broadberry, Custodis and Gupta, 2015). Broadberry et al. (2011, 2015)'s estimates, built on an output-based approach, thus show a persistent upward trend in GDP per capita which would have doubled between 1270 and 1700[5]. By use of a demand-side approach, Nuvolari and Ricci (2013) find that the English economy was rather "Malthusian" between 1250 and 1580, then showed capacity to relax some of the Malthusian constraints between 1580 and 1780, achieving a positive growth rate, although lower than those suggested by Maddison (2008) and Broadberry et al. (2011, 2015). Besides the construction of historical national accounts tracing the evolution of GDP per capita in Northwestern Europe and other regions of the world, a number of studies have also been produced to estimate preindustrial wages and thus check more precisely the hypothesis of "Little Divergence" of living standards across societies before the industrial revolution (see e.g. Allen, 2001, 2005a and 2009a; van Zanden, 2005a; Broadberry and Bishnupriya, 2006; Clark, 2007b; Hersh and Voth, 2009; Pamuk and van Zanden 2010; Allen, Bassino et al., 2011; Allen, Murphy et al., 2012) (Goldstone, 2015). According to the early modernists, the "Great Divergence" between Europe and Asia would thus root in a "Little Divergence" occurring during the centuries preceding the industrial revolution (Broadberry, 2014). By extension, a number of scholars have suggested to locate the origins of the industrial revolution and modern economic growth in this "Little Divergence" process, arguing that an initial rise in per capita income was crucial for the transition to industrialized society[6] and modern growth (see e.g. Galor and Weil, 2000; Hansen and Prescott, 2002) (Voigtlander and Voth, 2013b). Accounting for the "Little Divergence" has become a challenge for the early modernists. Testing a number of various hypotheses about the causes of the "Little Divergence" within Europe, de Pleijt and van Zanden (2013) have recently found that institutional changes, especially the rise of active Parliaments, and human capital formation were the primary drivers of the economic growth that took place in the North Sea Area of Europe between

[5] The great differences in views between Clark (2010a) and Broadberry et al. (2011, 2015) mainly come from highly conflictual estimates of English income around 1400-1450. While Clark (2010) estimates a relatively high income, leading to a Malthusian interpretation of preindustrial incomes in England, Broadberry et al. (2011, 2015) estimate a relatively low income, more consistent with the slow-but-modern view of English economic growth (Maddison, 2014).

[6] This argument has been especially brandished by the proponents of a demand-driven industrial revolution, who have moreover argued that a sustained increase in income was necessary to provide the required funds for industrial investment.

1300 and 1800[7]. Moreover, the study suggests that religion, i.e. the spread of Protestantism, might have played a key role as it affected human capital formation. These results highly contrast with previous Allen (2003)'s simulations, who reached the conclusion that the main factors responsible for the economic success in Northwestern Europe were the growth of American and Asian commerce and, especially, the innovations underlying the export of the new draperies in the 16th and 17th centuries, while the famous enclosures of the open fields, the representative government, and the spread of literacy – and so human capital - were relatively unimportant. In a recent paper, Broadberry (2014) has summarized the potential causes of the North Sea Area success already advanced in the literature. Among others, Broadberry highlights the role of the long trade distance, especially through its interaction with the institutions, the pastoral farming, and more generally the agricultural changes, the consumer preferences, the attitudes to work, and some demographic factors, in particular the European Marriage Pattern, which would have contributed to reducing fertility below the biological maximum, thus increasing the opportunities of investment in human capital (see e.g. Greif, 2006a; Foreman-Peck, 2011) and improving women's participation in the labor force (see e.g. de Moor, 2008; de Moor and van Zanden, 2010; Voigtlander and Voth, 2013a).

Did "Little Divergence" prefigure modern growth in the Western World? This question has been increasingly debated in the literature. While some scholars have positioned themselves in favor of a growth led - at least partly - by technological change and improvements in TFP (see e.g. van Zanden and van Leeuwen, 2011, 2012, Moller and sharp, 2014)[8], others have highlighted Malthusian mechanisms - changes of the birth and death schedules - to account for the increase in income per capita observed in preindustrial Western Europe. In a paper ironically entitled "*Malthusian Dynamism and the Rise of Europe: Make War, Not Love"*, Voigtlander and Voth (2009) thus claimed that two European "inventions", namely a peculiar marriage pattern and a specific mortality regime, might account for the increase in incomes observed between 1300 and 1800. Reasserting that productivity growth played only a little role in the evolution of the British and European GDP per capita between 1350 and 1700, Voigtlander and Voth (2013b) later developed a neo-Malthusian model with two sectors and multiple steady states to explain the rise in income per capita and urbanization during this period in Europe. The authors notably showed that a negative shock to population size - as the Black Death was (see also Pamuk, 2007) - might have triggered some of the demographic changes observed in the preindustrial period as it increased not only the real wages, but also (because of the supposed Engel law) the size of the cities - characterized by higher death rates - where the urban goods (the superior ones) were produced. Higher wages moreover

[7] Baten and van Zanden (2008) have also emphasized human capital, measured with data on book production, as a key determinant of economic performance in the centuries before 1800.

[8] Giving some credit to this view, Kelly and O Grada (2014a, 2014c) have reported evidence of productivity growth in some industries before the industrial revolution in Britain.

allowed higher levels of taxes, most of which were aimed at financing wars, whose effects on population size were negative. In the model, the increase in the death schedule induced by the initial shock on population size and the higher wages - a relation labelled the "horsemen effect"[9] - contributes to reducing the population pressure and makes higher equilibrium incomes sustainable. The idea that Malthusian population dynamics can raise the individual incomes in a subsistence economy and account for the widely accepted view that Western Europe was richer than Asia well before 1800 has been shared by several other scholars (see e.g. Clark, 2007a; Clark, 2008; Clark and Cummins, 2009; Clark, Cummins and Smith, 2012; Sharp et al., 2012). Thinking about the true onset of modern economic growth, Goldstone (2015) has also recently dismissed the idea of a "Little Divergence" launch pad for modern economic growth, arguing that a closer examination of the recent GDP per capita series reveals a pattern typical of pre-modern "efflorescences" in Britain and Holland, just as had occurred in earlier efflorescences in Song China and Renaissance Italy. As Goldstone (2015:1) wrote: "*According to the new data, at no point after 1600 and before 1780 did any nation in Europe experience both significant population growth and significant per capita income growth, as would be necessary for modern economic growth to have emerged. The new GDP/capita data make it clear that in fact China and Europe – both in their leading regions and overall – were on very similar economic trajectories until after 1800 […] Modern economic growth arose only in a late "Great Divergence" after 1800".* In Goldstone (2015)'s terms, something special happened to the British economy around 1800. This view is close to the one of Clark (2014) who strongly believes that the British industrial revolution was a singularity, a unique break in the world economic history.

3. The causes of the industrial revolution

The first waves of studies on the industrial revolution mainly sought to identify its social and economic effects: industrial production growth, development of cities, rise of the factory system, emergence of new social classes, etc. They highlighted the crucial role of technical progress in destabilizing the preindustrial societies but did not take a lot of effort to analyze the conditions underlying the appearance of the industrial revolution. The work of Mantoux (1906), one of the first historical syntheses of the British industrial revolution, was typical of this approach (Rioux, 1971). By contrast, the economic historian Ashton (1948) relegated the technological inventions to a lower level of priority, arguing that they were essential but could not emerge, bloom, and launch a process of modernization and sustained efficiency advance out of a favorable environment. As Mokyr (1999:12) claimed: "*Inventions do not rain down upon an economy like manna from heaven. They are stimulated by economic and*

[9] In the standard Malthusian models, the death rates are contrastingly typically downward sloping in income (preventive check hypothesis), while birth rates are either flat or upward sloping (positive checks hypothesis). See e.g. Nicolini (2007) and Kelly and O Grada (2012) for a test of these hypotheses in preindustrial England.

social pre-existing conditions. They emerge in the minds of some people for some reason which may or may not be identified, are communicated, adapted, refined, implemented, and imitated". In *The stages of economic growth: a non-communist manifesto*, Rostow (1960) proposed a development model defining five chronological development stages: traditional society, preconditions for take-off, take-off, drive to maturity and high consumption mass. This model has been heavily criticized, especially for its extreme linearity and its attempt to draw a universal model of development based on the unique Western World experience. Nevertheless, the model had the merit to rehash and intensify the debate around the idea of preconditions for take-off. The researchers have increasingly been interested in discovering these preconditions, or less restrictively the factors that favored the industrial revolution in Britain and Europe. This question has received much attention not just from historians and economic historians, but also from development economists who have viewed in the deep understanding of the industrial revolution the opportunity to design development policies in poor countries. The goal of this section is to carry out a survey of the main factors which have been advanced in the literature to explain why Britain was the first country to undergo a successful industrial revolution. As a preamble, it is worth noting that the notion that some factors were really indispensable for the industrial revolution has become increasingly hard to defend (Gerschenkron, 1962). As Mokyr (1999:19) brightly wrote: *Some factors present in Britain facilitated the Industrial Revolution and in this sense can be said to be causal. Others impeded its progress, and the Industrial Revolution proceeded in spite of them. The term 'facilitated' does not mean, however, that there were any elements that were indispensable. After all, factors that were neither necessary nor sufficient for the outcome can still be thought of as causal*. *For instance, heart attacks cause deaths, though not all deaths are caused by them and not all heart attacks are fatal. Moreover, insofar as heart attacks are themselves caused by other factors, it is debatable to what extent they are really ultimate causes or just 'transmission mechanisms*'. *The causal explanation of the industrial revolution runs into similar quandaries*".

A number of scholars have proposed to distinguish between the "proximate" explanations of the industrial revolution, those which themselves call for an explanation, and the "ultimate" causes of the industrial revolution, those associated with some "supposed" exogenous shock that could potentially account for the subsequent economic, political, social, and cultural changes that eventually led to the appearance of the industrial revolution (Cordoba, 2007). In the quest for the ultimate causes of the industrial revolution, some scholars have thus located the roots of this economic event into the English Glorious Revolution in 1688 (see e.g. North and Weingast 1989; Acemoglu and Robinson, 2012), the scientific revolution of the 16th and 17th centuries (see e.g. Musson and Robinson, 1969; Mokyr, 2005a, 2010a; Jacob, 1997, 2007 and 2014), the Great Discoveries at the end of the 15th century (see e.g. Acemoglu et al., 2005b; Cordoba, 2007) or even well back into the medieval times (see e.g.

Findlay and O'Rourke, 2007; van Zanden, 2008[10]). By contrast, one very typical example of a proximate explanation of the British industrial revolution is the theory developed by Bairoch (1963) in his thesis entitled *Révolution industrielle et sous-développement.* According to this Belgian economic historian, the British industrial revolution was caused, at least partly, by the British agricultural revolution that supposedly took place a bit before and during the industrial revolution. In line with Bairoch's view, agricultural progress was a sine qua non condition for British take-off as the modernization of the British agriculture seemingly was the only way to free up the economic resources, namely the labor and the capital, needed for the large-scale industrial development. Furthermore, the demand for industrial products coming from the changing agriculture would have provided the necessary stimuli to the British industry. But how could one explain agricultural progress without shedding light on some other factors?

According to Clark (2003:14), any convincing explanation of the British Industrial Revolution necessarily has to do with the following things. "*First explain why no society before 1800 - not ancient Babylon, Pharaonic Egypt, China through countless centuries, Classical Greece, Imperial Rome, Renaissance Tuscany, medieval Flanders, the Aztecs, Mogul India, the Dutch Republic - expanded the stock of knowledge by more than 10% a century. Then explain why within 50 years of 1800 the rate of growth of knowledge rose to modern rates in one small country on the margins of Europe, Britain. And of course explain why economies around the world have benefited from this knowledge expansion to such different degrees. Then we will understand the history of man*. Classifying the existing theories of the industrial revolution, Clark (2003) distinguished between the "exogenous growth theories", those which contend that exogenous events created the conditions needed for the industrial revolution to have taken place, the "multiple equilibrium theories", those which argue that a shock (disease, war, and so on) led the economy to move from the Malthusian equilibrium to the dynamic equilibrium, and the "endogenous growth theories", according to which the industrialization was written into the humanity's genetic code, i.e. dependent on the evolution of a state variable[11] which, beyond a certain critical threshold, triggered a new process of sustained efficiency advance. Aware of the huge complexity of the causal mechanisms at work in the appearance of the British industrial revolution, Mokyr (1999:19) strongly advocated in favor of "positive feedback and interactive path-dependent models", arguing that the monocausal, linear models based on concepts of equilibrium or steady states have huge difficulty doing justice to the historical reality. In Mokyr (2005b:288)'s terms, a satisfactory account of the industrial revolution has to deal with the following question: "*If technology was at the heart*

[10] Attempting to explain the origins of the British industrial revolution, van Zanden (2008) thus argued that the late medieval and early modern period, i.e. the period associated with the "Little Divergence" process defended by the "early modernists", was a long runway to the take-off of the industrial revolution.

[11] For instance the population size (see e.g. Galor and Weil, 2000), the market size (see e.g. Desmet and Parente, 2010), the stock of useful knowledge see (e.g. O'Rourke et al., 2013), or the evolution of individuals characteristics through natural selection (see e.g. Galor and Moav, 2002; see also Clark, 2007a).

of the Industrial Revolution, why was it changing at a rate more rapid and on a scale more widespread than ever before, and why did it accelerate in the nineteenth century instead of fizzle out?"[12] With perhaps the exception of those scholars attributing a quite important role to luck in the British industrial revolution (see e.g. Crafts, 1985b), economic historians have increasingly accepted the idea that the industrial revolution took place in 18th century Britain because a package of technological inventions came up to form a new "technical system" (Gille, 1978) in a quite favorable environment. For that reason, we need to observe the characteristics of the national and international environment in which Britain successfully undertook an industrial revolution.

a) Geography and natural resources

Britain's geography and geological conditions have often been highlighted to explain British economic success after 1750. Surrounded by sea, crisscrossed by rivers and penetrated by large estuaries, Britain, whose territory is characterized by the fact that no one place is more than 120 km far away from the nearest coast, benefited from advantageous geographical conditions for water transport. In addition to giving easy access to a relatively cheap and convenient transportation mode, which early stimulated the exchanges between the main British ports and coastal regions, the sea moreover constituted a natural barrier that likely dissuaded potential enemies from invading the country, thus contributing to maintain some relative peace and stability on the British ground. By the late 18th century, Britain had not been successfully attacked since 1066 and the great Norman invasion (Mokyr, 1999). Being an island might also have provided Britain with incentives to develop and permanently improve the navigation techniques that translated into British maritime superiority as from the end of the 17th century. Maritime power helped Britain to defend its territory, to win commercial wars, and to play an important role in international trade which contributed to stimulating the British industry. Along with some privileged geographical situation, Britain also supposedly enjoyed favorable geological conditions. Not only had the country abundant natural resources such as iron and non-ferrous metals (copper, zinc and lead, etc.), but also "*England was built upon an underground mountain of coal"* (Levine, 1987:97). Introduced on a large scale into the British economy to overcome the expected shortage of timber - Britain was one of the least wooded European countries - and meet the new fuel needs of the improving technology of transporting (Mokyr, 2010a), coal provided Britain access to huge quantities of cheap and powerful energy, especially as British coal was easily mined then transported by waterways.

[12] Crafts (1995, 1996) stated the central question associated with the industrial revolution in very similar terms.

The impact of natural factors on the economic inequalities among countries has always been subject to a large debate in the literature. If some scholars have given to such "accidents of nature" a quite determining role, others have tended to nuance them. It's nowadays widely accepted that Britain truly took advantage of its geographical environment to design its own industrialization path. Britain's access to relatively cheap water transport thus favored the adoption of coal on a large scale, the development of some specific industries, contributed to "crack open" local monopolies protected by high transport-cost barriers (Mathias, 1969), and promoted foreign trade. It has also been defended that the favorable water transport conditions in Britain helped the country to meet some of the necessary preconditions for take-off identified by Rostow (1960), especially the ones related to transport. But was really the British industrial revolution dependent on geographical factors? Tackling this question, Deane (1965, p.76) moderately wrote: "*If Britain had had to depend on her roads to carry her heavy goods traffic the effective impact of the industrial revolution may well have been delayed until the railway age*". The exact role of the British natural resources, especially the abundant presence of coal, has also been greatly discussed among scholars. Wrigley (1962) thus claimed that the substitution of inorganic material and fuels for the previously inorganic sources of raw material and power (wood and animal power), a phenomenon emphasized by other scholars (see e.g. Landes, 2003, Wrigley, 2004, 2010), was a sine qua non to take-off and industrial growth. Tracing the history of the coal industry, Church (1986:758) stated that "*it is difficult to exaggerate the importance of coal to the British economy*", summarizing the thought of several generations of (economic) historians (see e.g. Clapham, 1926; Nef, 1932; Ashton, 1948; Deane, 1965; Braudel, 1981)[13] who placed coal at the heart of the story of the industrial revolution. Quite in the same vein, Sieferle (2001) argued that the early use of fossil energy in Britain, due to the rarefaction of British wood, explained why this country undertook first an industrial revolution. By contrast, Germany, a country characterized by the presence of large wooded areas located next to rivers, remained longer dependent on a traditional energy regime. Pomeranz (2000) also attributed the British economic success to the accessible reserves of mineral resources, especially coal, near population centers. In line with this view, Ridley (2010a, 2010b) identified coal as the material account for the British industrial revolution and the subsequent modern economic growth: "*without coal, Britain would be just another flash in the pan, a golden age that produced some luxury and culture and science but no real transformation of living standards".* Several "cliometric" studies (see e.g. McCloskey, 1981; Crafts, 1985a, Mokyr, 1990; Crafts and Harley, 1992; Clark and Jacks, 2007) have yet tended to seriously downplay the role played, directly or indirectly, by coal and the coal industry in British industrialization (Clark and Jacks, 2007). Based on historical coal rent series, Clark and Jacks (2007) have thus found that the English possession of coal reserves actually made a negligible contribution to industrial revolution incomes. Relying on Kanefsky (1979) and Crafts (2004)'s estimates, O Grada (2014a:12) reaches the conclusion that "*steam's* - and so coal's – *role at the height of the industrial revolution, both as a source of energy relative to waterpower and in terms of its contribution to overall economic growth,*

[13] Cited in Clark and Jacks (2007).

was distinctly secondary". In the same vein, Mokyr (2010a:101) stated that "*besides steam engines and iron smelting and processing, radical new uses for coal during the industrial revolution were not that many".* Although being one defender of the materialist approach, Clark (2010b:1) sustained that coal was the "wrong materialism" and could not account for the upturn in innovative activity during the industrial revolution: "*Without a single ton of coal being dug from the ground in England 1760-1860 there would still have been an industrial revolution*". Clark (2010b) defended his position by notably showing that coal did not prove to be essential for the textile inventions, the transport infrastructure, and the improvements in sailing ships. Testing various accounts of the British industrial revolution in the framework of a simple dynamic model, Borowiecky and Tepper (2015) also very recently concluded that coal played a minor role in the British breakout from Malthusian dynamics.

In reality, it's highly difficult to assess the exact role of coal in the British industrialization. In particular, it is not clear how resource availability plays on technological progress (Mokyr, 1999). On the one hand, resource abundance is often seen as fortunate as it reduces the production costs and makes potentially viable the expansion of a whole "technical system" (Gille, 1978) based on its large-scale industrial use. On the other hand, resource scarcity is also likely to encourage creativity and innovation by imposing some stimulating challenges to the economy. Mokyr (1990:160) thus noted: "*In the absence of coal, the ingenuity applied to using it would have been directed towards replacing it"*. In his recent book entitled *The Enlightened Economy,* Mokyr (2010a:101-102) reaffirmed his position, contending that *"the industrial revolution didn't absolutely need steam…, nor was steam power absolutely dependent on coal"*. According to this view, coal wasn't a driver for technological progress. It truly shaped the British industrial revolution but did not create it. Resources endowments, as well as demand factors, would then work as a "steering mechanism", or what Rosenberg (1969) called a "focusing device", leading to a national bias in technological activity (Kuznets, 1965). "Thus, *coal-rich Britain focused on Newcomen engines, while coal-poor Switzerland found economic success in precision-intensive low-energy industries such as watchmaking and engineering*"[14]. Britain's technological creativity, defined as its ability to develop new inventions and adapt them to its highest benefit, would so have been much more crucial. Yet it might still be argued that Britain's particular advantage in producing economically valuable inventions was partly due to the presence of natural resources and coal on its territory. For instance, the extraction of coal, through mining activities, induced the invention of the high-potential steam engine which was later implemented with success in other industries like the textiles and the metallurgy. In reality, at the times of the British industrial revolution, we do not know whether the industrial world opened by coal and its large-scale exploitation was more promising than the one that would have possibly emerged in the absence of coal resources. Whatever their exact role in the British industrial revolution, the geographical and geological factors, like most other causal factors proposed in the abundant literature, were

[14] Mokyr (1999:22).

hardly either necessary or sufficient (Mokyr, 1999). As Britain, Ireland and Japan are also islands. Britain and France, based on Verley (1997)'s calculations, had comparable amounts of naturally navigable rivers. The United Provinces of the Netherlands also enjoyed good conditions for internal transportation (Mokyr, 1999, 2000a) and furthermore had virtually access to cheap coal which was not a British monopoly (Clark, 2010b). China, Russia and the United states possessed huge reserves of coal on their territories. And coal was anyway a traded commodity. International trade could theoretically absorb, at least partly, national inequalities in natural endowments. This argument, among others, led Mokyr (1980, 1985) to discredit the notion that pre-famine Ireland failed to industrialize because of a lack of readily available coal.

As for Britain, similar factors, based on geographical and geological conditions, have often been advanced in the literature to explain the "Great Divergence" between Europe and the rest of the world, and especially East Asia. For instance, Diamond (1997) pointed out the relatively high number of kilometers of coastline (per square kilometer of surface) which Europe is endowed with, compared to other regions in the world. According to this author, this privileged access to sea and the Atlantic favored international trade and the subsequent accumulation of wealth in the Western European countries. In his book entitled *The great divergence*, Pomeranz (2000) contended that Europe's divergence from the Old World was largely the consequence of the fortunate location of coal, which progressively substituted for timber in Europe, and trade with the Americas. In a critical review of the book, Vries (2001) summarized Pomeranz's account of the European industrial revolution using the expression "Coal and colonies". In agreement with Sachs and Warner (1997)'s proposal that biological and geographical factors can affect the rates of technological change and economic growth, Abramson and Boix (2014) argued that the good climate and quality of soil in Europe might have affected positively the agricultural yields, thus spurring both population growth and urbanization. According to these authors, the access to the Atlantic, through foreign trade, also contributed to fostering the development of urban agglomerations[15]. The cities, in turn, supposedly provided an environment conducive to technological progress, and especially to labor-saving technological inventions (see e.g. Habakkuk, 1962; Allen, 2009b, 2010). Without stating any opinion on whether coal played a causal role in the European industrialization, Fernihough and O'Rourke (2014) have incidentally shown that coal was a strong determinant of the city population size, accounting for around 60% of the growth in the European city populations between 1750 and 1900.

[15] Other scholars have also put emphasis on the military conflicts in a fragmented European continent as a key determinant of the rise in European urbanization - as cities were better protected, i.e. defended and fortified, than rural areas - before the industrial revolution (e.g. Rosenthal and Wong, 2011; Dincecco and Onorato, 2015).

b) Demography

An original feature of the 18th century is the evolution of the number of men in Britain and Europe (Habakkuk, 1953). Indeed, a sustained growth of the European population started as from the beginning of what Michelet called the "Great century". Many authors have seen in this demographic expansion the signs of the final victory of life. Between 1000 and 1700, the European population (including Russia) rose from 43 million to 125 million of individuals (Biraben, 2003). This evolution corresponded to an average annual growth rate of around 0.15%. Over this period, different phases of demographic crisis and growth followed each other. The phases of demographic growth were often observed in times of relative peace and political stability, and modest economic development. The phases of demographic crises resulted above all from the three misfortunes - also labelled the "three horsemen of the Apocalypse" or the "three mortal fates" (Sauvy, 1963) - of those times, i.e. the epidemics, the wars and the famine, which hit cyclically the European populations. If the diseases (smallpox, dysentery, plague, etc.) and the wars (Hundred Years War, Thirty Years War, Dutch war, Anglo-Dutch war, etc.) had quite terrible devastating effects, the most frequent demographic disaster was likely the dearth (Desaive et al., 1972). After a poor harvest, due for instance to catastrophic weather conditions, the food products, especially the cereals, became scarce and so highly expensive, leading to an increase in mortality rates. Against the backdrop of any demographic analysis, it is very important to keep in mind that agricultural performance was a crucial element influencing both food safety and mortality. The 17th century was characterized by a stagnation of the European population, accompanied with dramatic periods of demographic decline in some countries such as Germany, North Italy, Spain and France (Verley, 1997). But everything changed starting from the end of the 17th century in Britain, and a bit later in the rest of Western Europe, where a process of sustained demographic growth progressively took shape (Flinn, 1970, 1981). Between 1700 and 1800, the European population indeed rose from 125 million to 195 million of individuals (Biraben, 2003). In reality, the acceleration of the population growth really took place in the second half of the 18th century. The French population increased by slightly more than 7 million of individuals between 1700 and 1789, amounting around 28 million of citizens on the eve of the French Revolution (Dupaquier, 1988). In one single century, i.e. between 1710 and 1810, the population almost doubled in England (Wrigley and Schofield, 1981; Clark, 2010a). It also increased dramatically in countries such as Ireland, Germany, Russia, Italy, Belgium and the Netherlands, pushing the European nations to introduce or generalize the official censuses intended to collect data and information about population. Although the question is still largely debated in the literature, the growth of the British population in the 18th century seems to have been the combined result of a rise in the crude birth rate and a fall in the crude death rate (Wrigley and Schofield, 1981; cited in Galor, 2005:226). Besides the general rise in the European population, Kelly and O Grada (2014a) pointed out great demographic differences among European countries. For instance, life expectancy at birth in England was

higher than in France at dawn of the industrial revolution[16]. As Kelly and O Grada (2014a:14-15) noted, "*true, the gap was largely due to lower infant and child mortality, but this still means that survivors of childhood in England were less likely to be scarred by disease than their French counterparts, with attendant advantages in adult height and health. Recent research on the impact of adverse shocks (e.g. being conceived or born during a famine) or pro-active interventions in utero and during early childhood (e.g. better medical care and nutrition) points to significant long-term implications for adult physical and mental health and, indeed, also cognitive penalties (e.g. Malucio et al., 2009; Hatton, 2011; Barham et al., 2013; Currie and Vogl, 2013). Surely it is not implausible to extend that link to the past?"*

A number of scholars (see e.g. Deane and Cole, 1962; John, 1965; Eversley, 1967; Perkin, 1969; McKendrick et al., 1983) have emphasized demographic expansion as a factor likely to explain the timing of the British industrialization. The Economics Nobelist Hicks (1939:302) even suggested that "*perhaps the whole industrial revolution of the last two hundred years has been nothing else but a vast secular boom, largely induced by the unparalleled rise in the population*". Taking a more cautious position, other scholars have argued that population growth contributed significantly to economic changes in Britain (e.g. Habakkuk, 1971; Lee and Schofield, 1981). By contrast, only a few continental scholars have paid great deal of attention to the economic consequences of population expansion (Anderson, 1996). The proponents of the demographic account have highlighted both demand and supply factors to define the various channels through which population growth might have triggered or spurred a process of industrialization. On the demand side, the demographic expansion increased the total volume of desired goods and services in the economy and so would have made necessary the emergence of a new economic growth based on technical progress. An alternative demand-side view contends that the rise in demand (larger consumption market) would have fostered both investment and innovation by creating a much less risky business environment for entrepreneurs and modifying their expectations. This refers to the typical Keynesian argument (Anderson, 1996). On the supply side, population growth potentially raised the number of available workers, and thus would have contributed to reducing wages, as well as some economically harmful rigidities in the labor market. This, in turn, would have promoted new entrepreneurial ventures and innovative activities. Moreover, population growth would have guaranteed the presence of readily available workers for the industrial development. Some scholars such as North and Thomas (1973) have also shed light on the potential effects of the population pressure on the development of new growth-friendly institutions (secure property rights, etc.).

[16] While the rise in adult life expectancy was evident in the case of the English elite as from the 17th century (see e.g. Johansson, 2010; Cummins, 2014), it became more general during the 18th century see (e.g. Landers, 1993; Wrigley et al., 1997) (Kelly and O Grada, 2014a).

Although appealing at first glance, some major criticisms can be addressed to this quite simple determinist view of the relation between population growth and industrialization. Population growth was not an invention of the 18th century. Some episodes of demographic expansion had already previously occurred in Britain and Europe without creating anything that looks like an industrial revolution. Furthermore, Europe was not the only region in the world to exhibit a population growth in 18th century. Other regions, such as China and Central America, were also growing in population. Why did not these regions take off? The current experience of the Third-World nations, although it truly takes place in a radically different world, also tends to prove that an acceleration of the population growth is not enough to set into motion a cumulative process of industrial growth. Population growth was not a sufficient condition, especially as the potential relation between demography and industrialization was, at best, an indirect one. The increase in the total volume of desired goods and services arguably induced by the population growth couldn't indeed translate into effective demand for manufactured goods and economic growth per capita without supply-side adjustments and technical progress (for instance in agriculture) capable of providing the extra population with new resources and thus overcoming the propensity for the marginal productivity of labor to fall (see e.g. Wrigley and Schofield, 1981:443-449; O'Brien, 1985:786; Hudson, 1992:160; Anderson, 1996:267). But, as Anderson (1996:267) noted, "*there is no theoretical reason why population pressure should induce these. Indeed, in the alternative way, it was only because they were taking place anyway that population growth could continue"*. Using a technologically static model in which capital and land are assumed to be constant, Mokyr (1985) estimated that population growth could not account for more than 10% of the rise in the industrial output between 1750 and 1850. However, the model fails to take into account different elements including the Keynesian argument, that is the potential positive effect of population growth on the return to capital, for instance in house building and transport, and so on investment and innovation (More, 2000). The scholars who locate population growth at the heart of the story of the industrial revolution actually have to make recourse to some dynamic argument that explicitly links the population size or growth and technological change or productivity growth (Boserup, 1981: cited in Mokyr, 1985). This idea of induced innovation[17], although it has been formalized by several scholars (see e.g. Becker et al., 1990; Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992; Kremer, 1993; Kortum, 1997; Segerstrom, 1998; Galor and Weil, 2000; Kögel and Prskawetz, 2001; Jones, 1995a, 2001; Galor, 2005, 2011), is far from being uncontroversial (see Jones, 1995b; Voth, 2003; Mokyr, 2005c; Lagerlof, 2006; Clark, 2003, 2005a, 2014). Not only the effect of population growth on demand and technical progress, but also the widespread idea that demographic growth encouraged labor mobility and provided the expanding industry with readily available workers has been greatly challenged in the literature. Many scholars have notably argued that the labor mobility remained low by those times, both sectorally and geographically (compare Wallis, 2014). Additionally, the industrial use of the workforce was not determined by the overall demographic conditions, but rather by both the sectoral and

[17] The origins of this idea are sometimes located in the work of Simon (1977, 2000)

regional characteristics of the labor markets. The rural overpopulation in Britain in the first half of the 19th century was thus not incompatible with the fact that entrepreneurs, at least in some regions and/or sectors, had strong difficulties in recruiting skilled workers (Verley, 1997). According to Drake (1969), the British industrialization, at least before 1815, did not contribute to use an excess additional workforce. It might even be that the British industry innovated to compensate for the shortage of skilled workers. This point introduces the two competing and incompatible views of the role of labor in the British industrial revolution (see e.g. Mokyr, 1999; Wallis, 2014). The first one, closely associated to Habakkuk (1962)'s work, considers technology as the enterprise's response to labor scarcity. Labor scarcity - and the resulting high wages - was so friendly to industrial growth as it induced the introduction of labor-saving technologies[18]. If some scholars have indeed acknowledged the existence of labor shortage in some British counties such as Lancashire (see e.g. Anderson, 1996), others have rejected the evidence of any labor scarcity in Britain (see e.g. Flinn, 1966). The second view, based on what Mokyr (1976) called the growing-up models, suggests that industrial progress was more likely to happen in areas in which labor, considered as a scarce resource, was abundant and cheap (see e.g. Lewis, 1954; Pollard, 1978)[19][20].

Developing around the idea that modern economic growth emerged as the result of a close interplay between demographic and economic changes, a highly-influential literature has increasingly tried to provide theories able to explain both the economic and demographic transitions within the same framework. These unified growth theories seek to account for the passage from a Malthusian regime to a modern growth regime (economic transition), as well as for the underlying causes of the decline in the fertility rates (demographic transition). The industrial revolution and the demographic transition are then seen as different aspects of a single economic event (Lucas, 2002). In these growth models, much of the economic acceleration goes through the fall in fertility and the increase in educational standards, i.e. the accumulation of human capital (see e.g. Galor, 2005; Clark, 2014). Possible mechanisms for generating a drop in fertility and a progressive switch to sustained modern growth are, among others, the exogenous technological progress (see e.g. Greenwood and Seshadri, 2002), the institutional change (see e.g. Jones, 2001), changing marriage institutions (see e.g. Gould et al., 2008), the introduction of new contraceptive technologies (see e.g. Strulik, 2014), the compulsory schooling (see e.g. Sugimoto and Nakagawa, 2010), increasing basic knowledge (see e.g. O'Rourke et al., 2013), structural change associated with an increasing share of population investing into education (see e.g. Doepke, 2004), the natural selection favoring the parents with higher preference for educated children (see e.g. Galor and Moav,

[18] The thesis of an industrial revolution induced by high wages, and cheap coal, has been recently defended by scholars like Allen (2009b, 2010) and Broadberry and Gupta (2009).

[19] In a recent paper, Kelly, Mokyr and O Grada (2015) thus empirically find that industrialization was restricted to low wage areas, while energy availability had little impact.

[20] See Mokyr (1999, 2010a) for a critical analysis of these two views.

2002)[21], rising time cost of raising children (see e.g. Lagerlof, 2003, Hazan and Berdugo, 2002; Doepke and Zilibotti, 2005, Boldrin et al., 2005), rising adult life expectancy (see e.g. Cervellati and Sunde, 2005 and 2007; Soares, 2005; Vogel, 2011), population growth or size (see e.g. Becker et al., 1990; Kremer, 1993; Galor and Weil, 2000; Kögel and Prskawetz, 2001; Galor, 2011), population density (see e.g. Boucekkine et al., 2007), and declining mortality (see e.g. Kalemli-Ozcan et al., 2000; Kalemli-Ozcan, 2002, 2003; Boucekkine et al., 2002; Lagerlof, 2003; Doepke, 2005; Soares, 2005; Tamura; 2006) (Vogel, 2011). All these theories provide seemingly consistent explanations for the industrial revolution and the subsequent increase in living standards in Western countries. In particular, these theories shed light on different mechanisms through which the transition from a Malthusian equilibrium to a new dynamic one (modern growth) characterized by low fertility rates might have occurred. But, as Bar and Leukhina (2010:425) noted, "*the relative importance of each such mechanism for the case of a particular country remains unclear"*. This statement joins Mokyr (2005c:1147)'s earlier claim that "*the exact connection between the demographic changes and the economic changes in the post-1750 period are far from being understood*". The existing theories indeed disagree on the main driving forces behind the economic and demographic transformations. As a result, it's not clear whether demographical factors, including the emergence of the "European marriage pattern"[22] by the late Middle Age - a phenomenon characterized by comparatively late marriage and low fertility rates in the North Sea Area[23] - triggered the economic transition to modern growth and led technology (Mokyr, 1990; Clark, 2007a; Khan, 2008). In an original paper, Bar and Leukhina (2010) even suggested that the demographic and economic transitions could have potentially occurred independently of one another, still recognizing that some causal links might explain their real "proximity". Voigtlander and Voth (2006:320) also criticized the unified growth theories, stating that "*what is really missing is a better understanding of why some countries overcame stagnation at radically different points in time*. Attempting to address this criticism, Galor (2011) formulated the hypothesis that cultural, religious, geographical (natural resources, etc.), political (propensity to trade, etc.) or institutional (secure property rights, management of knowledge, etc.) factors may account for the differential timing of transition from Malthusian regime to growth across countries. In *The Handbook of economic growth*, Clark (2014) recently pointed out a set of empirical challenges faced by the economic theories modeling the actual world of the British industrial revolution in the attractive child quantity-quality framework. For instance, the fall in the aggregate fertility rates - although the latter were substantially lower in England than in France on the eve of the industrial revolution (Wrigley and Schofield, 1983) - did not occur

[21] Clark (2007a) found evidence in support of this hypothesis, with the richest having more surviving children, thus favoring the spread of "middle class" or "bourgeois" values from the elite to the rest of society.

[22] This term was coined by Hajnal (1965).

[23] A recent literature has emphasized the European Marriage Pattern as being central to the economic success of both Britain and Northwestern Europe (see e.g. Greif, 2006b; de Moor, 2008, de Moor and van Zanden, 2010, Greif and Tabellini, 2010; Foreman-Peck, 2011; Voigtlander and Voth, 2006, 2009 and 2013a; de Pleijt and van Zanden, 2013). See Dennison and Ogilvie (2014), who have contrastingly refuted the notion that the European Marriage Pattern was the cause of the European economic success, for a critical review of this recent literature.

before the late 19th century in Britain. A number of studies (see e.g. Clark and Hamilton, 2006; Boberg-Fazlic et al., 2011; Clark, 2014) have even shown evidence of a positive link between net fertility and economic status in pre-industrial England[24]. However, this pattern truly disappeared for marriages between 1780 and 1879. The evidence of higher returns to human capital, which would have acted as a powerful economic signal in favor of investment in human capital, is also lacking for the period traditionally associated with the industrial revolution (see e.g. Clark, 2003; 2005a, 2014; Clark and Cummins, 2015; compare Klemp and Weisdorf, 2012)[25]. In these conditions, why did people, especially the richer families, change their fertility behavior starting from the late 18th century?

c) Agricultural progress

According to converging estimates, agricultural productivity would have more than doubled in Britain between 1700 and 1850, just at the time of the industrial revolution (Deane and Cole, 1967; Crafts, 1985a; Allen, 1994; Overton, 1996a) (Clark, 2005b). Over the same period, the British population was multiplied by approximatively three. The estimates of agricultural productivity however vary in where exactly they place the productivity growth, reflecting a huge debate in the literature concerning the true timing of the British or English agricultural revolution. From the late 19th century, the standard view among economic historians (see e.g. Toynbee, 1884; Mantoux, 1906; Ernle, 1961; Mingay, 1963; Deane, 1965; Chambers and Mingay, 1966; Beckett, 1990; Campbell and Overton, 1993; Martins, 1993; Overton, 1996a, 1996b) used to locate the agricultural revolution in the late 18th and early 19th centuries in a movement narrowly linked to the industrial revolution (Allen, 1999). Productivity growth was traditionally associated with different features including the parliamentary enclosure of land (see McCloskey, 1972), the introduction of new farming technologies like the seed drill, the introduction of new crops and crop rotations, and various improvements in livestock breeding (Thomas, 2005). These developments were supposedly promoted and facilitated by key innovators such as Jethro Tull, Charles Townshend, Robert Bakewell and Thomas William Coke. For instance, Tull is known to have brought significant improvements on the plough, thus contributing to economizing on expensive inputs like men and horses (Griffin, 2010). He is also traditionally credited with the invention of the seeder. Exploiting rationally the system of enclosures, Bakewell, sometimes considered as one of the fathers of modern zootechnics, made great advance in the field of drainage and adopted the systematic selective breeding of livestock. Townshend popularized the four-field rotation system which was already in application in Flanders, and studied its effects on various crops like wheat, turnips, barley and clover. In agreement with the standard view, Overton (2011) wrote: "*it is difficult to*

[24] Interestingly, Vogl (2015) recently found the same demographic patterns for currently developing countries.
[25] Such evidence became somewhat more obvious during the second half of the 19th century (see e.g. Long, 2006).

avoid the overwhelming mass of evidence from a wide variety of sources that points to the period after 1750 as witnessing an agricultural revolution". Yet a large number of revisionist historians (see e.g. Havinden, 1961; Jones, 1965; Kerridge, 1967, Crafts, 1985a; Allen, 1992; Clark, 1998a, 1998b, 2002b) have criticized the standard view, some of them arguing that the major agricultural changes and much productivity growth took place earlier. In line with this thought, the industrial revolution is then viewed as the result of a long prior phase of agricultural expansion. For instance, Kerridge (1967) pointed out the quite important role played by up-and-down husbandry in the period 1560-1660. Using a scientific model of nitrogen, Allen (2008c) eventually concluded that the agricultural revolution actually took several centuries, the time frame needed for agricultural yields to rise from medieval to 18th century levels. As Tarlow (2007) noticed, "*in general, over the past few decades the tendency has been to push back the period of revolution from the nineteenth century to find its origins in the fifteenth century or even earlier. It has been pointed out that few of the 'innovations' of the eighteenth and nineteenth centuries were actually new; most of the new crops and new techniques had been known and used somewhere in England for decades or even centuries.* Bridging to some extent the standard and revisionist views, Allen (1999) supported the idea of two agricultural revolutions. The first one, mainly accomplished by the yeoman, would have preceded the period of parliamentary enclosures, i.e. the second half of the 18th century, while the second one would have occurred in the first half of the 19th century. By contrast, the period conventionally associated with the beginning of the British industrial revolution would be characterized by the stagnation of British agricultural output and productivity[26], a result shared by other scholars (see e.g. Turner et al., 2001; Clark, 2002a). The existence of a phase of agricultural progress following the British take-off has likely led some historians (see e.g. Verley, 1997) to consider that the English agricultural revolution was the daughter, and not the mother, of the industrial revolution. In contradiction with Allen (1999, 2000, 2005b) and Clark (2002b)'s view, some scholars (see e.g. Apostolides et al., 2008; Banerjee, 2009; Broadberry et al., 2013) have recently shown evidence of a sustained rise in British agricultural output per worker throughout the 18th century, a finding which supports or better fits the standard stories of productivity gains. In parallel with the studies estimating productivity growth in the British agricultural sector during the preindustrial period and the industrial revolution, a number of papers (see e.g. Fogel, 2004; Allen, 2005b; Broadberry et al., 2011, 2015; Floud et al., 2011; Muldrew, 2011; Kelly and O Grada, 2013; O Grada, 2014b; Meredith and Oxley, 2014; Harris et al., 2015) have recently provided estimations of food supply - net agricultural value added plus net imports - measured in calories per head of population in England. Unsurprisingly, these estimations are subject to large heterogeneity as well. While Fogel (2004) and Broadberry et al. (2011, 2015) estimate per capita supplies at around 2,200 kcals in both 1750 and 1800, Kelly and O Grada (2013) find significantly higher levels, more compatible with the disappearance of the positive check - in the sense of the short-run response of mortality to price and real wage

[26] In a following paper, Allen (2000) even found a drop in agricultural output per worker in the period 1750-1800.

shocks - by the late 18th century in England (see e.g. Kelly and O Grada, 2014b) and the advantage of England over France in terms of mean adult height, real wages, life expectancy, and labor productivity in agriculture (Kelly and O Grada, 2014a).

Reflecting in some way the debate on the true timing of the English agricultural revolution, the sources of agricultural progress have also been heatedly debated among agrarian historians. For instance, a number of scholars (see e.g. Clark, 2005b; Overton, 2011) have qualified the macroeconomic consequences of the agricultural practices pioneered by the "Great Men", such as Jethro Tull and Charles Townshend, commonly connected to the English agricultural revolution. Regarding the new farming practices, Clark (1987) even went as far as to dismiss technological change as a key factor able to account for agricultural productivity growth in Britain before 1850. According to Clark (1987, 1999), agricultural progress, before 1850, was not revolutionary in nature, but part of a more gradual process of modernization which contributed, among others, to a more intensive use of the labor factor. In line with this view, Clark (2005b:49) noted: "*when we get down to the level of what was happening in the fields and the barns during the Industrial revolution period we see little sign of any major changes".* Studying the archaeology of improvement - including rural improvement - in Britain over the period 1750-1850, Tarlow (2007), by contrast, mentioned the rise of a supposedly consensus on a nuanced version of the traditional 18th to 19th century English agricultural revolution. Accordingly, the 18th and 19th centuries England witnessed the large-scale diffusion of some innovations that had emerged much earlier in some parts of Britain. Measuring technology in the agriculture by the use of data related to patents and new book titles on agricultural methods, Ang et al. (2010, 2013) also reached the conclusion that technological progress played a significant role in boosting productivity growth in the British agriculture between 1620 and 1850 (Ang et al. 2013) and inducing the British industrial revolution (Ang et al., 2010). In the tradition of the papers studying the relation between climate and demography (see e.g. Galloway, 1985, 1986; Appleby, 1979, 1980) or agriculture (see e.g. Overton, 1989; Michaelowa, 2001; Turner et al., 2003; Brunt, 2004, 2015; Hoyle, 2013; Waldinger, 2014; Dalgaard et al., 2015), Martinez-Gonzalez (2015) found that the crucial driving forces behind the English agrarian revolution were the climate, which supposedly improved in the first half of the 18th century, population growth[27], and the capacity of adaption, especially of small farmers. With respect to the last point, Allen (1992, 2009b), by contrast to many historians who have first and foremost emphasized the role of the parliamentary enclosures and the rise of the agrarian capitalism, a phenomenon whose timing is unclear (Shaw-Taylor, 2012)[28], thus often claimed that agricultural progress,

[27] On this point, Martinez-Gonzalez (2015) joins Boserup (1965)'s conclusions. The latter, contrary to Malthus, rather emphasized the role of population growth on agricultural production, and not the other way round.

[28] As Shaw-Taylor (2012:2-3) wrote: "*the key point to emerge from this literature […] is that historians have found evidence of engrossment (the growth of larger farms through the absorption of smaller ones) in the fourteenth, fifteenth, sixteenth, seventeenth and eighteenth centuries but there is no consensus as to when the critical developments occurred".*

at least before the industrial revolution, was also greatly due to the action of the small-scale farmers in the open fields.

Agrarian historians have actually believed in a British agricultural revolution mainly for two reasons (Clark, 2005b). The first reason is that by 1850 the British agriculture had reached levels of land and labour productivity which were significantly higher than in most European countries. Yet, as Clark (2005b:51) noted, "*despite the popularization of the concept of the agricultural revolution by Toynbee and Lord Ernle as long ago as the 1880s, agrarian historians have been singularly unsuccessful in pinning down the details of what allowed this revolutionary improvement in land and labor productivity. Enclosure of common lands, the elimination of peasant agriculture, and new crops such as turnips and clover, have all been placed center stage in the drama of the agricultural revolution. None of these actors has proved up to playing the lead role in a dramatic agricultural revolution*". In reality, the task of the agrarian historians is extremely difficult as reliable data on agricultural output and inputs are missing before 1866. No agricultural statistics were indeed produced at a national level until then. As a result, the estimates of productivity growth in agriculture cannot rely on direct estimates of agricultural outputs and inputs. Aware of this challenge, many scholars (e.g. Tarlow, 2007; Hudson, 2014) have drawn attention on the fragility of productivity estimates which would be critically dependent upon the chosen method of calculation, the set of assumptions and the sources used to infer prices, rents, levels of employment, and so on. Kelly and O Grada (2014a:23) even severely stated that "*estimates of productivity growth in agriculture before the industrial revolution range so widely that very little useful can be inferred from them*". The second reason why agrarian historians have largely admitted the existence of a British agricultural revolution is because three major phenomena occurred in the British economy as a whole: population growth, increasing incomes and urbanization. As Clark (2005b:51-52) wrote: "*The agricultural revolution accepted by such writers on the Industrial Revolution like Crafts (1985a), Harley (1993), Allen (1994), O'Brien (1996), and Overton (1996a, 1996b) is the one that is derived mainly from population, income, and urbanization*". English population indeed rose from 2.56 million of individuals in 1500 to 17.59 million by 1850 (Clark, 2010a). Between 1550 and 1850, the real national income per capita in England was almost multiplied by two (Clark, 2010a). Broadberry et al. (2015) recently found the same multiplying factor for the evolution of British GDP per capita over the period 1270-1700. If the share of the population living in cities ranked well below the European average around 1500, England proved to be the most urbanized European nation other than the Netherlands by 1800. According to Shaw-Taylor and Wrigley (2014), the English population living in towns with 5,000 or more inhabitants rose from 3.2% to 43.5% between 1600 and 1850. In parallel, Allen (2009b)'s findings suggest that the fraction of the total workforce in agriculture dropped from 75% to 35% between 1500 and 1800. For the period stretching from 1710 to 1850, Shaw-Taylor and Wrigley (2014)'s estimates show a fall of agriculture in total employment (for males aged twenty and over) from 49.8% to 26.9%.

Agricultural progress has always been at the heart of the debate concerning the origins of the British industrial revolution. In *Capital,* Marx already highlighted the dramatic role of the enclosures that supposedly favored the capital accumulation in the British agriculture and contributed to form, through a movement of expropriation, the first industrial battalions and the proletariat. In line with the approach giving a key role to the agriculture, Rostow (1960) even raised agricultural progress to the level of a "precondition for take-off". The underlying logic is simple. As the agricultural sector captured a great part of the economic resources in preindustrial societies, the industrial revolution could seemingly not take place without prior improvement in the agriculture. Bairoch (1974) later extended the Rostowian growth model by shedding light on the effects of the changing agriculture on the demand for industrial goods. According to Bairoch, agricultural progress contributed not only to freeing up some economic resources for the industry but also to stimulating industrial production. Indeed, the modernization of the British agriculture required investment in equipment goods, such as metal-made tools and machines, provided by the British industry. Moreover, agricultural progress arguably spurred a process of demographic growth that supposedly translated into effective demand for industrial consumption goods. Rostow's focus on agriculture actually espoused well the ideas of Adam Smith who had understood very early the potential role of agricultural progress in the economy. In *An Inquiry into the Nature and Causes of the Wealth of Nations,* Smith (1776) already stressed the importance of the agricultural surplus which could potentially be transferred to other sectors of activity through various channels like direct investment, the taxes and the exportations. Yet the Rostowian model, including the Bairoch's extensions, has been heavily criticized in the literature. For instance, Crouzet (1967, 1985) contested some of Bairoch's calculations and challenged the notion that the British agriculture contributed in a decisive way to industrial growth in the early stages of the British industrialization (see also O'Brien, 1985; Crafts, 1985a). Crouzet notably showed that the first modern production units in the iron/steel industry were mainly oriented to non-agricultural markets, such as shipbuilding and exports. Many other criticisms arose over the extreme linearity of the Rostowian model which indeed supposes that a take-off was impossible in the absence of any prior large-scale modernization of the agricultural sector. The precedence of an agricultural revolution over an industrial revolution is however not empirically well verified in the first successful economies, with the possible exception of Britain (Rioux, 1989). Some French historians (see e.g. Morineau, 1968, 1971 and 1974) have thus concluded to the absence of an agricultural revolution - or what E. Labrousse called a "cultural revolution" - in France before 1840. Taking the argument over, Richet (1968) even contended that it was rather the cities, new poles of growth, which stimulated the French agriculture, not the other way round. The argument of a (urban)-demand-driven agricultural development, which stressed the role of the cities' growth in agricultural progress, has been used by several other scholars to explain why Northwestern Europe was the world's most productive region in agriculture until 1800 (see e.g. de Vries, 1974; Boserup, 1981; Wrigley, 1987, 1988; Grantham 1989, 1999; Kussmaul, 1990; Hoffman, 1996; van Zanden, 1999; Allen, 1998, 2000 and 2008b; Weisdorf, 2006; Campbell, 2010) (Kopsidis and Wolf, 2012).

Tackling this question, Mokyr (1985:21) claimed that it would be "*unreasonable to think in terms of a necessary sequence of agriculture first, industry next*". According to Mokyr, the British industrial revolution largely fed itself as it provided agriculture with non-agricultural inputs that improved food production and distribution over the 18th and 19th centuries. *For example, the modernization of transportation* - which allowed, among others, a greater specialization in the British agriculture - *affected the supply of agricultural products in a way similar to improvements in agricultural productivity properly speaking*[29]. Furthermore, Mokyr (1985) argued that the British industrialization contributed to a more intensive use of labor in the agriculture, thus joining partly Clark (1987)'s conclusions on the causes of agricultural progress in Britain.

The origins of the industrial resources, namely the industrial capital and labor, have been abundantly debated in the literature. In Britain, Marx's thesis has been strongly qualified. In particular, the role of the enclosures on the capital formation (see e.g. Allen, 2008b) and agricultural employment (see e.g. Chambers, 1953; Gullickson, 2002; compare Snell, 1985) wouldn't be statistically confirmed. The agricultural workforce actually remained roughly constant between 1700 and 1850, at about 1.5 million workers (Griffin, 2010:65). In line with this observation, a number of scholars (see e.g. Chambers and Mingay, 1966; Jones, 1974) concluded to the absence of massive transfers of workers from the South green England to the industrializing North during the 18th century. In the same vein, Crouzet (1967) rejected the notion that agriculture provided the British industry with a large number of workers, at least in the early stages of the industrial revolution, especially as the labor reallocation process was hampered by a low labor mobility, both geographically and sectorally, and a generous poor relief system (see e.g. Williamson, 1990; compare Wallis, 2014). In this respect, Verley (1997) noted that the rural exodus, which truly led many rural people to join the (industrial) cities with the hope of a better life, took place only after the take-off. This point is consistent with Shaw-Taylor and Wrigley (2014)'s recent statement that "*urban growth* [in England] *had been dramatic in the 16th and 17th centuries but had halted in the 18th".* In reality, the labor reallocation process described by Rostow seems quite logical as long as its implicit hypotheses are not questioned (Verley, 1997). First, it takes heroically for granted that full employment was reached in the first successful economies. Secondly, it makes the assumption that agricultural and industrial activities were mutually exclusive, or to be said differently that the rural workers could not contribute to industrial production. This assumption is obviously open to criticism, especially with the development of the theories on proto-industrialization that have moreover brought to light the existence of massive seasonal unemployment in agriculture before the industrial revolution (see e.g. Mendels, 1972; Gullickson, 1983; Ogilvie and Cerman, 1996). Thirdly, the Rostowian model

[29] The idea of agricultural improvements as positive externalities of the large-scale development of the modern sector is largely present in the recent growth literature. See e.g. Matsuyama (1992, 2008), Grossmann (2013) and Rajhi (2014).

assumes the existence of a unified labor market characterizing by a perfect professional and geographical mobility. Conclusions about the labor mobility in 18th century Britain yet seems to be highly dependent on the profile of the workers, the regions and the geographical scale (see e.g. Williamson, 1990; Anderson, 1990; Allen, 2008b; Wallis, 2014). Fourthly, it neglects the opportunities of specialization offered by international trade. Fifthly, it does not take into account the role of demographic expansion that could potentially explain how industry might have grown without taking lots of workers away from the agriculture. The source of the industrial capital has also animated lots of discussions among scholars. These discussions have actually been part of a larger debate about the role of capital formation in the British industrial revolution. Most of the debate developed around the idea formulated by Lewis and Rostow in the 1950s that a take-off could not occur without a sudden upward leap of the national gross investment rate. According to Rostow (1960) and Bairoch (1974), capital accumulation necessarily took place in the agriculture. In line with this view, agricultural progress and the reorganization of the agricultural sector, which led to the concentration of land revenues, were crucial to finance the industrial revolution. Without neglecting the role that agriculture might truly have played in funding the British industrialization, a number of scholars have put emphasis on other potential sources of capital accumulation, for instance colonial and international trade (see e.g. Marx, 1867; Williams 1944; Frank 1978; Wallerstein 1974, 1980; Pomeranz, 2000). International trade indeed increasingly expanded as from the Great discoveries and contributed to enrich the Western European nations involved in trade, especially those having well-endowed colonies. At that time, mercantilism reigned supreme in Western Europe and favored the inflows of precious metals, thus contributing to the development of monetary economies (Hamilton, 1934). Due to the lack of reliable data, it is however very difficult to come up with any formal conclusion about the ulterior use of the capital accumulated in agriculture and international trade, especially as this capital could have financed indirectly some industrial activities, notably through the banking and the fiscal channel. Nevertheless, there seems to be evidence that part of this capital turned away from industrial investment and was rather invested in public bonds, commercial activities, lands and properties, or simply hoarded. Concerning the capital from trade, a number of scholars have contended that the profits from trade were far too modest - or too modestly invested in the British industry - to have had any direct role in the causation of the British industrial revolution (see e.g. Engerman, 1972; O'Brien, 1982; Acemoglu et al., 2005b). In the same vein, Mokyr (1985) argues that the contribution of the profits from trade to the European capital accumulation was insufficient to justify any Europe's advantage. With respect to the agriculture, Allen (2008b) defended that this sector did not release large quantities of capital by reducing its demand for investment, and that agricultural surplus did not prove to finance massively the industrial capital formation in Britain, thus endorsing Postan (1935:2)'s view that little of the wealth of rural England "*found its way into the new industrial enterprises*". In agreement, Crafts (1985a) also calculated that agricultural savings funded only little non-agricultural investment. Assessing the different channels through which the industrial sector might have financed its development, Crouzet (1965:172) finally concluded that "*the capital*

which made possible the creation of large-scale factory industries in Britain came…mainly from industry itself". According to this economic historian, most of modern industrial firms were able to self-finance their expansion. This result corroborates the widespread belief that the primitive capital, as well as the financial markets, played only a small role in launching the British industrial revolution. The financial innovations, introduced all along the 18th and 19th centuries, would thus have been more crucial in a second stage when technical progress made necessary the purchase of very costly equipment goods and the adjustment of the industrial facilities (Cottrell, 1980). Summarizing in some way this view, Mokyr (1999:63) stated that "*there is little evidence that the financial markets were instrumental in helping modern industry more than vice versa*". Some scholars have yet pointed out the importance of international markets and foreign capital, especially the capital coming from Holland (see e.g. Wilson, 1966), for funding the British industrialization (see e.g. Chenery and Syrquin, 1975; Crafts, 1983; Neal, 1993; Brezis, 1995).

Did agricultural progress really contribute to the British industrial revolution? According to Allen (1999, 2008b), the answer is very dependent on the true timing of the British agrarian revolution.. Did the British agricultural revolution precede the industrial revolution, or was it rather coincident with it? As Clark (2005b:50) said, *a diffuse revolution occurring precisely at the time of the Industrial Revolution implies that the gains of the Industrial Revolution period most likely stemmed from some economy wide social or institutional change - changed attitudes on the part of all producers as in Jan de Vries' Industrious Revolution, or improved incentives for all economic actors as in North and Weingast's analysis of the Glorious Revolution of 1688, or superior incentives to move labor out of agriculture as argued by O'Brien (1996).* Believing in a British agrarian revolution prior to the British industrialization, Allen (2008b:116) thus stated that "one *reason why the industrial revolution could proceed in the face of a largely static agriculture was that agriculture had already revolutionised itself between 1600 and 1750*". In the same vein, Crafts (1985c) contended that agriculture did release labor between 1500 and 1750 when the agricultural share of the population fell. In agreement with this view, de Pleijt and van Zanden (2013) attributed great part of the British success to the structural or occupational change that occurred over the period 1300-1800, a phenomenon statistically confirmed by recent Shaw-Taylor and Wrigley (2014)'s estimates. Borowiecki and Tepper (2015) also defended that structural change away from agriculture was likely one of the main drivers of the British breakout from Malthusian dynamics, as it increased the sustainable population growth, i.e. the rate at which the British population could expand without triggering declining living standards. Finally, Deane (1979:48) wrote that "*if the agricultural industry did not actually supply the labor which the labor intensive techniques of the new industry demanded, it fed the increasing population from which the industrial labor force was drawn"*, thus joining Crafts and Harley (2004)'s view. Looking for the exact role of agriculture, Zangheri (2005) rather noticed that agricultural progress could hardly be considered as a sufficient condition for the industrial revolution to have occurred.

By way of illustration, Zangheri (2005) showed that the agricultural advances observed in the most flexible societies/economies of medieval Europe did not produce anything that would look like an industrial revolution. Mokyr (1985:21) went so far as to question the necessary character of agricultural progress, advocating that "*it is unwarranted to infer that because agricultural growth affected industrialization, the latter could not have taken place without the former*". Giving seemingly support to this view, more recent studies have shown that the role of agricultural progress on industrialization needs to be seriously reconsidered when switching from the context of a closed economy to the context of an open one. In a pioneer work, Matsuyama (1992) thus developed an endogenous growth model which predicts a positive link between agricultural progress and economic growth (industrialization) for the closed economy case - a result shared by many other scholars (see e.g. Sato and Niho, 1971; Murphy et al.,1989; Laitner, 2000; Caselli and Coleman, 2001; Kögel and Prskawetz, 2001; Eswaran and Kotwal, 2002; Gollin and al., 2002; Voigtländer and Voth, 2006; Francisco and Markus, 2011; Gollin and Rogerson, 2014; compare Bustos and al., 2015) - but a negative link for the open economy case. In line with this result, Clark (2002b) reached the conclusion that the growing English population, at least during the period of the industrial revolution, was fed mainly through food imports and switching agricultural output towards food products, not through an agricultural revolution. In a review of John Hicks (1942)' book entitled *The social framework,* J.R. Hicks (1999) already wrote: "*If England had been obliged to support her population entirely from her own soil, there can be little doubt that England would have experienced a* [demographic] *disaster before the nineteenth century was over. In fact, in the years before improvements in ocean transport made it easy to import foodstuffs on a great scale, food in England was very scarce; the Corn Law agitation was the sign of a real scarcity, the premonitory symptom of what might have grown into a much greater calamity. As it was, the cheapening of transport made it possible for the English people to draw upon the ample supplies of agricultural land in the New Worlds of America and Australia, and so to remedy their own shortage. But how was it possible for the English people to save themselves in this way, and not possible for the Irish to do so as well? The reason is that imports have to be paid for. If the agricultural land available in England was becoming small relatively to the population, England possessed other natural resources, in the form of coal and other minerals, and she was continually adding to her man-made equipment, her factories and mines, her ships and her railways. All these resources enabled her to produce a plenty of goods which she could exchange against foodstuffs from overseas*. Although he put emphasis on agricultural progress before 1750 as a key factor of the British industrialization, Allen (2008b:115) still recognized that "*if one asks how British agriculture fed the expanding population during the industrial revolution, the answer is - badly*".

d) Demand-side factors

Some part of the literature devoted to identifying the causes of the industrial revolution has suggested that the technological inventions of the late 18th century Britain were driven by demand, both domestic and foreign. In a pioneer work, Gilboy (1932) already highlighted the parallel role that demand should have played at the time of the industrial revolution. In a more recent paper, O'Brien and Engerman (1991) showed that even small variations in demand could potentially move a country from one economic track to another, thus giving credit to the demand-side factors (Mokyr, 1999). The demand-driven approach implicitly assumes that the aggregate supply curve shifted because of a rise in the aggregate demand. Technological change would so have constituted the original entrepreneurs' response to the rising demand for British manufactured products. Proponent of the demand-driven account of the British industrialization, McKendrick (1982) first introduced the concept of *consumer revolution* to describe the *"large and rapid increase in the consumption of consumer goods such as tableware, curtains, pictures, and cutlery, a lust for objects"* (Clark, 2010c:1) that supposedly occurred in the period 1600-1750. As McKendrick (1982:9) wrote: "*A consumer revolution occurred in England in the 18th century along with the Industrial Revolution….The consumer revolution was a turning point in the history of human experience*". The concept of *consumer revolution* has been empirically funded, at least partly, on probate inventories, the major source of information on material life in England between 1600 and 1750, which seem to show a rise in English households' material possession over the 17th and 18th centuries (see e.g. Weatherill, 1988, 1993; Shammas, 1990; Styles, 1993; Overton et al., 2004)[30]. The idea of a consumer revolution has yet been challenged in the literature, especially by scholars who fail to observe any parallel rise in real day wages in Britain. As an attempt to provide a solution to this apparent incompatibility and rescue the concept of *consumer revolution*, de Vries (1994, 2008) then came up with a new theory of *industrious revolution* to describe the set of changes in household behavior that supposedly took place in the 17th and 18th centuries in Britain and Northwestern Europe. According to this theory, British households, both male and female individuals, started to work harder in order to increase their level of consumption, thus becoming more industrious, i.e. more market-oriented (Koyama, 2009). In economic terms, the British households became more willing to trade leisure for money as the relative utility of income was increasing along with the rise of a market society, which in turn translated into larger demand for industrial goods[31]. In parallel to the *consumer revolution*, and the attendant *industrious revolution*, a number of studies have brought to light the early existence in Britain of a large (urban) consumer class whose living standards were comparatively high on the eve of the industrial revolution, due in part to agricultural and commercial progress (see e.g. Bairoch, 1974; Wrigley, 1985; Allen, 2001, 2003, 2008a, 2009b, 2010; Maddison, 2008; de Vries, 2008; Persson, 2008; Broadberry et al.,

[30] Cited in Clark (2010c)
[31] Also see Galor and Weil (1996).

2011, 2015). Interestingly, Allen and Weisdorf (2011) considered that a consumer revolution was more likely to happen in rural areas, thus joining styles (2002)'s conclusions. The high degrees of British urbanization and living standards or income[32], which were reflected to some extent in the development of a consumer society in the 17th and 18th centuries Britain (see e.g. McKendrick, 1974; McKendrick et al., 1982; Weatherill, 1988, 2006; H.C. Mui and L.H. Mui, 1988; Hoh-Chueng and Lorna, 1989; de Vries, 1993; Fairchilds, 1993; Lemire, 1984, 1992, 1997; Berg and Clifford, 1999, Berry, 2002; Stobart and Hann, 2004; Berg, 2004, 2005; Reis, 2005; Vickery, 2006; Styles, 2006, 2007; McCants, 2007; Hersh and Voth, 2009), have often been advanced in the literature to account for the British economic success after 1750 (see e.g. Habakkuk, 1962; Wrigley, 1967; de Vries, 1984, 1994, 2008; Voigtlander and Voth, 2006; Allen, 2009b, 2010; Brunt and Garcia-Penalosa, 2012; Abramson and Boix, 2014). The advantages of cities - where the wages were traditionally higher (see e.g. Habakkuk, 1962; Allen, 2009b, 2010) - for promoting growth, and more specifically technological change, have been greatly discussed in the literature. On the demand side, it has mainly been advocated that cities provided large consumption markets that favored new entrepreneurial ventures and innovative activities, as well as the development of a large-scale industry characterized by a much finer division of labor. In *An Inquiry into the Nature and Causes of the Wealth of Nations*, Adam Smith (1776) early emphasized the importance of the consumption markets size in determining the production volume and the production scale of the firms. And Smith strongly believed that the specialization - and so the division of labor - was one of the most important channels through which technological change occurred, thus joining many other scholars' view that the market size is a crucial determinant of innovation (see e.g. Sokoloff, 1988; North, 1990, Engerman and Sokoloff, 1997, Khan and Sokoloff, 2001, Sokoloff and khan, 1990, 2000; Desmet and Parente, 2010, 2012, 2014). In addition to providing large markets for better and cheaper goods, the cities would also have contributed to developing different institutions such as the public services and the intellectual property rights (see e.g. Sokoloff, 1988; Sokoloff and Khan, 1990, 2000 and 2001; Khan, 2002) (Nair-Reichert and Weinhold, 2009), as well as the transportation technology as the cities were dependent on supplies from the countryside. The modernization of the transport infrastructure, in turn, played a key role in the British industrialization (see e.g. Szostak, 1991). Rostow (1960) even identified the modernization of the transport infrastructure as a precondition for take-off. It has often been argued that the improvements in transportation, combined with the absence of important internal trade barriers, contributed to creating very early a more integrated and unified consumption market in Britain, by comparison with most European countries, thus favoring the expansion of a large-scale industry (see e.g. Chartres, 2003; McCloskey, 2010a). The idea of demand-driven technological change can also be found in the *leapfrogging* or *bottleneck* models - presented by David Landes (1969) - in which a sudden increase in the

[32] Urbanization rates have been widely used as a guide to - indicator of - preindustrial per capita income and economic development in the literature. Highly critical of this approach, Clark, Cummins and Smith (2010) pointed out the risks of such indicator given that many rural workers were engaged in manufacturing, services and trade.

productivity of one sector or activity, such as weaving, generates a demand for technological progress in another complementary sector or activity, such as spinning (Mokyr, 1999).

Although increasingly popular, the demand-side factors, including population growth, are however more difficult to integrate into the industrial story. Indeed, supply and demand are not symmetrical in long-term economic change (Mokyr, 1977). As Mokyr (1999:39) wrote, "*if the industrial output increased and technology possibly changed because of a rise in demand for industrial goods, it has to be made clear why demand increased in the first place. Changes in demand are not exogenous to an economic system*". A large number of scholars have thus criticized the demand-driven approach, emphasizing that most inventions of the industrial revolution arose in already existing markets like the textiles, the metallurgy, and the paper industry (see e.g. Mowery and Rosenberg, 1979). Production growth on those markets may consequently be interpreted as technical progress shifting the supply curve to the right along the demand curve. The consumer revolution, defined as the key causal factor for the British industrial revolution, has also met many objections in the literature. For instance, due to the chronological gap between the peak of the British consumer revolution (1680-1720) and the industrial revolution, Weatherill (1988) concluded that the two phenomena were largely independent from each other. If changes in the household consumption behavior possibly triggered the British industrial revolution, other scholars wondered why the Dutch Republic, which has often been considered as the first modern economy regarding its preindustrial level of urbanization and income per capita or living standards (see e.g. de Vries, 1974, 1984, 2008; van der Woude, 1980; de Vries and van der Woude, 1997; Mijnhardt, 2010; de Jong, 2011; van Zanden and van Leeuwen, 2012), did not become the cradle of the industrial revolution. As v.d. Heuvel and Ogilvie (2013:70) wrote: "*the Dutch Republic* - where the income per capita was 50% higher than in Britain by 1700 (Maddison, 2003) (Mokyr, 2010a) - *is universally regarded as the first economy to experience an explosive transformation in retailing that enabled broad masses of consumers to shift from household to market consumption and production*". With respect to the supposed British industrious revolution, Allen and Weisdorf (2011) found evidence of an industrious revolution among British rural farmers in the second half of the 18th century, thus joining Voth (2000, 2001)'s results, but showed that the phenomenon was the consequence of economic hardship, and so did not feature any sign of a *consumer revolution*. On this last point, v.d. Heuvel and v.n Meerkerk (2014) drew attention on the fact that the alterations in work practices might not have only resulted from a changing consumer behavior in the restricted form of what de Vries (1994, 2008) called an *industrious revolution*, a phenomenon that incidentally required quite well-established market institutions (see e.g. Ogilvie, 2010, van den Heuvel and Ogilvie, 2013). In a recent paper, Clark (2010c) went as far as to refute the existence of any British consumer revolution over the period 1600-1750. Indeed, Clark rather assimilated the phenomenon to a statistical artifact resulting from a misinterpretation of the probate inventories. Concerning the potential role of the cities in the British industrial revolution, Mokyr (1995) argued that

the supply-side factors associated to urbanization - which supposedly consisted in providing environments highly conducive to the positive externalities and economies of agglomeration and scale highlighted by the economics of growth, as well as to the diffusion, through human interactions, and the preservation of information and knowledge (see e.g. Boserup, 1981; Jacobs, 1969, 1984; Bairoch, 1988, 1991; Glaeser et al., 1992; Audretsch and Feldman, 1996; Hall, 2000; Duranton and Puga, 2001, 2002 and 2004; Glaeser, 1994, 2010; Brunt and Garcia-Penalosa, 2012; Hartwick, 2015) - likely played a more important role than the demand-side factors[33]. Mokyr (1995:25) also emphasized one effect of the lack of centralization of the political power in Britain, i.e. the "*relative unimportance of London as an administrative and cultural center when compared to other European capitals such as Madrid, Paris, Saint Petersburg, or Vienna*", as one possible advantage for Britain in the race for industrialization. Thinking more generally about the "demand-driven" hypothesis of the British industrial revolution, Mokyr (1999:41) eventually concluded that supply was the more interesting and important historically: "*an autonomous and prior shift of the industry demand curve was not an essential part of the story*". It does not mean that demand had no influence at all on the British inventions of the late 18th century. For instance, demand can potentially have a great impact on technological activity when it turns from an industry, or a segment of an industry, which does not exhibit a high innovative potential, or is more simply resistant to innovation, to another industry (Mokyr, 1999). The examples of cotton and coal might perfectly illustrate this point for Britain. In the 17th century, cotton was mainly imported from India (in the form of calicos) through the commercial activities of the East India Trading Company. Cotton was then traditionally used to manufacture various items such as drapes and clothing. More comfortable than wool and cheaper than silk, the cotton fabric became increasingly popular and fashionable in the eyes of British households (Fisher, 2012). In spite of the introduction of the Calico Act, passed in 1721 and then repealed in 1774, the British cotton industry thus surprisingly continued to develop as the prohibition was in practice widely evaded. This, in turn, contributed to expanding the British ports of the west coast. By way of illustration, the county of Lancashire, which houses the port of Liverpool, remarkably grew into one of the most important epicenters of the British cotton industry, due in part to favorable climate conditions (good level of damp) for the yarn spinning operations. It has often been argued

[33] As Mokyr (1995:24-25) wrote: "*The absence of anything looking remotely like an industrial revolution in the environment of the largest towns of Europe, from Madrid to Vienna, suggests that whatever the case, the demand-side effects were not sufficient […] In the century and a half before 1800, the smaller provincial cities of Britain had grown and prospered, in contrast with those of the continent (De Vries, 1984). Many of the great industrial towns that were to play central roles in the industrial revolution experienced their formative years in these years. These cities were "relatively open, fluid, competitive and acquisitive" (Corfield, 1982:97), characteristics clearly conducive to technological creativity. In cities such as Manchester, Birmingham, Derby, Sheffield, Glasgow, and Leeds, a profoundly important exchange of information occurred in Scientific and Philosophical Societies, where engineers, scientists, and businessmen met and discussed technical issues. Beyond these formal organizations, people met in coffee houses, at public lectures, and in private homes for instruction and discussion of technological problems. At these places, the great minds of the industrial revolution, such as Watt, Smeaton, Roebuck, Wedgwood, Rennie, Henry, Keir, and many others, were able to meet and trade ideas and suggestions. By their very nature, these societies were urban in nature, and without cities the typical low-brow, pragmatic technological orientation of British intellectual life might not have come about*"

that the demand shift towards cotton-made goods, whose manufacture was much easier to mechanize, helped to increase not only the production but also the rate of technological progress in the textile industry (see e.g. Mann and Wadsworth, 1931). In the same vein, some scholars have highlighted the role of demand for the rapid growth of the coal industry. Based on new constructed series on coal rents, the price of coal at pithead and at market, and the price of firewood, Clark and Jacks (2007) thus concluded that the rise in demand for coal during the industrial revolution did more for the expansion of the coal industry than the technological innovations in mining.

e) Trade and empire

On the eve of its industrial revolution, Britain was a country characterized by a relatively high degree of openness. People, both emigrants and tourists, and capital moved in and out of the country with ease. British Intellectuals were free to correspond and exchange their ideas with colleagues over the Channel and across the Atlantic (Mokyr, 1999). The share of foreign trade in British NNI - net national income - amounted to around 9% in the mid-18th century, making Britain one of the world's greatest trading nation, then rose to around 16% by 1800 (Clark, 2010a). Enjoying privileged access to sea and the most powerful navy in the world, Britain, which was guided by a pronounced colonial spirit, increased the level of its exports and imports all over the 17th and 18th centuries (see e.g. Cain and Hopkins, 1993; Morgan, 2000; Harley, 2004; Daudin et al., 2010). This expansion of trade was accompanied by the growth of the British ports, such as Liverpool, London, Bristol or Glasgow, and contributed to the economic development of the harbors' hinterlands, especially those active in textiles. British exports essentially consisted of industrial products like cotton goods, woolen goods, ironwares and manufactures. In 1700, the woolen products represented around 69% of all British exports[34]. This share progressively declined in the 18th century to reach more or less 20% in 1800. British exports of cotton products really took off in the second half of the 18th century. Between 1770 and 1830, a period which witnessed the introduction of great textile inventions, the share of cotton goods in British exports increased from around 2% to 44%. In the same time, British imports of raw cotton exploded. The commercial circuit is well known. The colonial workforce, especially the one from North-America, provided Britain with the necessary raw cotton. Cotton-made goods were then produced in British industrial centers and either consumed domestically or exported to the rest of the world[35]. If the non-textile industry accounted for a relatively small proportion of British exports in 1700, it increased its participation to foreign trade in the 18th century, thus reinforcing the growing dependence of the British industry on international markets. In the 18th century, British imports consisted

[34] Data on the sectoral patterns of British foreign trade is from Clark (2010a).
[35] See e.g. Davis (1979) and Crouzet (1980) for a discussion on the role of the cotton textile trade in the British industrial revolution.

overwhelmingly of raw materials like raw cotton, wool, linen, silk and timber, and foodstuffs like grains, sugar, tea and wine. A substantial part of the tropical products imported from the colonies was reexported with huge profit, mainly to Europe. Not only the sectoral patterns but also the geographical patterns of British foreign trade changed over time. While Europe absorbed around 85% of British exports in 1700, the proportion fell to 30% in 1800 and 48% in 1830[36]. At the same time, the American share rose from 10% in 1700 to 57% in 1800 and 38% in 1830. This evolution translated a great reinforcement of the trading partnership with the USA that seemingly offered a promising market to the British industrialists. The share of the rest of the world in British exports - including Asia whose importance remarkably rose between 1770 and 1830 (Solar, 2013) - increased from around 4% in 1700 to around 12% in 1800 and 14% in 1830. Even though British exports expanded rapidly during the industrial revolution period, it should be noted that Britain did not adhere to a regime of free trade before the 1840s (Fremdling, 2004). International trade indeed remained strongly controlled in Europe until the mid-19th century when protectionism started to be viewed as a limit to economic development, and particularly in Britain which henceforth sought to consolidate its economic supremacy. The liberal watershed was really initiated in Europe when Britain abolished the Corn Laws[37] in 1846, in part due to the pressure of the British industry, and the Shipping Acts in 1849. An economic free trade agreement was concluded between Britain and France in 1860. If the free trade dynamics rapidly spread out to other countries like the Zollverein, the Netherlands, Belgium, Switzerland and Russia, the German Customs Act of 1879 constituted the starting point of a new protectionist period that intensified after the 1929 crisis and lasted until the end of the Second World War.

International trade, one of the most visible forms of economic activity, has always received attention from scholars in the quest of the causes of the industrial revolution in Northwest Europe, especially in Britain and France, two coastal countries that possessed colonies and proved to be early involved in trade. The proponents of the trade account have usually made recourse to two basic arguments. The first one is that foreign and colonial trade gave access to goods which were not available at home or could not be domestically produced with the same level of efficiency. This argument refers to the *real gains* of international trade. The second argument is that international trade opened up new markets which were necessary for industrial expansion and progress. Since the publication of Toynbee (1884)'s *lectures on the industrial revolution in England,* successive generations of economic historians have thus pointed out the role of British foreign trade as a powerful engine of industrial progress, thus joining many growth theorists' view (see e.g. Dollar, 1992; Sachs and Warner, 1995; Ades and Glaeser, 1999; Frankel and Romer, 1999; Alesina et.al., 2000; Dollar and Kraay, 2003,

[36] Data on the geographical patterns of British foreign trade is from Barbier (2011, table 6.4).

[37] The Corn Laws constituted a set of regulatory texts adopted in Britain between 1773 and 1815. They set the framework for cereal exchanges with the other countries. For instance, the Corn Law Act of 1815 forbade the importation of cereals when prices dropped below a certain threshold.

2004; Alcala and Ciccone, 2004) (Ahmed, 2012). As Sachs and Warner (1995:3) wrote: "*Trade promotes growth through a myriad of channels: increased specialization, efficient resource allocation according to comparative advantage, diffusion of international knowledge through trade, and heightened domestic competition as a result of international competition".* Deane and Cole (1967:83) thus claimed that "*there is no doubt of the central importance of overseas trade in the expansion of the British economy*". In the same vein, O'Brien and Engerman (1991) sustained that the British exports were not solely important but also necessary to British industrial growth in the 18th century. Allen (2003:432) stated that "*intercontinental trade boom was a key development that propelled Northwestern Europe forward"*, especially as trade openness accelerated the structural transformation in the northwestern European countries, i.e. the process of labor reallocation from agriculture to industry, which supposedly accounted for most growth[38]. Connecting the relationship between trade and economic growth to the British industrialization, Habakkuk and Deane (1963) contended that demand coming from trade propelled the new Industrial Revolution industries. In line with this view, Cuenca (1997:900) advocated that "the *overseas demand in general provided the opportunity and the stimulus for technological innovation as the industry reached the limits of growth within a protected domestic market*". Looking for the origins of the "Great Divergence", Pomeranz (2000) argued that one of the key differences able to explain why Britain, and not China, experienced an industrial revolution in the late 18th century is that Britain enjoyed privileged access to the raw materials of the New World. The historian of the "slave trade" Inikori (2002) also attributed British economic success to overseas trade, considering that Britain was the first case of an export-led industrialization in human history. In the wake of Acemoglu et al. (2005b)'s work, which accounts for British rise to economic superiority by a close interplay between the Atlantic trade and the institutional constraints on the executive power in Britain, Cordoba (2007) located the roots of the British industrial revolution into the colonization era which supposedly provided Britain with an expanding set of trading and exploitation opportunities in Europe and Asia, as well as in the New World[39]. Assessing the role of trade, Clark, O'Rourke and Taylor (2008) stated that "*the magnitude, scale and transforming power of the Industrial Revolution lay in its unification of technological advance with the military power that generated easy British access to the markets of Europe, the Americas, the Near East and the Far East*", thus giving support to Findlay and O'Rourke (2007)'s view that early trade in Britain was the consequence of some comparative advantage coupled to the "musket and the cannon"[40]. Allen (2009b, 2010) was recently convinced to have found the Holy Grail, the solution to the puzzle of the timing and location of the industrial revolution, by developing a new theory placing trade at the center

[38] See also Crafts and Harley (1992, 2000 and 2004).

[39] In contradiction with this view, although not irreconcilable, Epstein (2000) pointed out the importance of a strong centralized state, rather than the constraints on the executive, to guarantee the existence of a unified national market and overcome the economic barriers of political fragmentation (Broadberry, 2014).

[40] In the same vein, Hoffman (2012) argued that the economic consequences of Britain and Europe's military power, symbolized by a great domination in the gunpowder technology, were huge, from colonialism to the slave trade and even the industrial revolution.

of his accounts. According to this author, British success in trade contributed to increasing urbanization, and so creating a unique wage and price structure in Britain, characterized by comparatively high wages (international standards) and cheap energy, which supposedly induced the labor-saving technological inventions of the industrial revolution. Foreign trade moreover would have modified positively the internal rate of return for industrial investment, thus encouraging the "technological bet" in the British industry.

Yet the idea of a trade-driven industrialization is far from being consensual in the literature. While it is widely acknowledged that technological change boosted British exports as from the second half of the 18th century - reflecting to some extent the notion that economic growth is ultimately a supply-side phenomenon (Mokyr, 1977; McCloskey, 1981; Daudin et al., 2010) -, the exact role of foreign trade and overseas demand in triggering or inducing technological change and industrial progress is still heatedly debated. As Krugman (1995) noted, the question is more controversial in that direction. Thus, Flinn (1966) emphasized the domestic market - which seemingly was large enough to cover the expenses of every individual entrepreneur (Mokyr, 1999) - as the mainspring of technological change and industrial growth in Britain. In line with this view, Davis (1979:62) claimed that "*overseas trade did not have an important direct role in bringing about the Industrial Revolution*". In the same vein, Thomas and McCloskey (1981:102) concluded their study by stating that "*in the late 18th century, the strongest effect between commerce abroad and industry at home was from industrialization to commerce, not the reverse. Trade was the child of industry*". The same conclusion was reached by trade theorists such as Kindleberger (1964) and Findlay (1982) (Mokyr, 1999). Convinced by the "home grown" nature of the industrial revolution on the supply side, Mokyr (1985:23) noted that "*the gains accruing to the British economy from foreign trade were not necessary to achieve the gains from productivity growth. Given that technical progress occurred, however, its beneficial effects were enhanced by the expansion of trade*" - mainly through learning by doing and experience. Very recently, Borowiecki and Tepper (2015) also found that trade played only a minor role in the British breakout at the time of the Industrial revolution. According to all these theories placing the home market at the center of the industrial story, the growing dependence of the British economy on foreign markets during the industrial revolution period, a phenomenon well documented in a recent study of Clark, O'Rourke and Taylor (2014), was an ex-post economic reality, not something that initially drove industrial growth and technological change.

Another facet of what Palma (2015) called the "revisionist literature" has rejected the idea that international trade was the decisive trigger of the British industrial revolution because of the relatively small share of the external sector in early modern Britain's economy. But as Mokyr (1999:44) wrote, "*any inference regarding the 'importance' of exports based on what proportion of output was exported is highly suspect*". A high rate of trade openness does not

necessarily mean that the gains from trade are important for a specific country, especially if the country's technology and endowments, in terms of both natural resources and factors, are identical to those of its trading partners. In the extreme case of full employment, it may even be harmful if trade diverts massively national resources from domestic consumption (McCloskey, 2010a). In the opposite case, a low rate of trade openness does not necessarily mean that foreign trade is not crucial for a specific country, especially if the country imports resources that are not available at home or only at huge cost. In Britain, the goods that were imported like the tropical products (tea, sugar, tobacco, etc.), the European foodstuffs (wine, corn, et.), and the raw materials, especially raw cotton, all proved to play an important role in the British economy, and some of them were critical inputs in the British industry (Mokyr, 1985; Findlay, 1990). In a recent paper, Clark, O'Rourke and Taylor (2008:2) concluded that the history of the British industrialization would have been very different in case substantial trade barriers would have prevented Britain from having access to the external markets it did exploit: "*British incomes per person, instead of rising by 45% between the 1760s and 1850s would have risen by a mere 5%. The TFP growth rate, already a modest 0.4% per year, would have fallen to 0.22% per year*". This conclusion highly contrasts with Harley (1994)'s previous findings[41] but is more in adequation with many scholars' view that the gains from trade were actually important in Britain and that British real income would have been much lower in the context of a closed economy (see e.g. Wrigley, 1987; O'Brien, 1999; Ormrod, 2003; Acemoglu et al., 2005b; Allen, 2003, 2009b and 2010; Palma, 2015). The aggregate statistics on the British external sector would hide the real effects of international trade on British economy, especially as British exports were overwhelmingly composed of industrial goods and highly specialized in a few industries, the ones that Rostow famously called the leading sectors of the British industrial revolution. By providing stimuli to these industries, foreign trade might have favored the emergence of new technologies that, in turn, might have generated positive spillovers to the rest of the economy. This refers to the potential dynamic effect of international trade on industrialization and economic growth. The dynamic argument has also been brandished by scholars who believe that foreign trade promoted the development of growth-friendly institutions in Britain (see e.g. Braudel, 1980; Acemoglu et al., 2005b; Cordoba, 2007). As Harley (1994:307-308) noted: "*Trade might not have greatly increased per capita income but it created the cities and classes that challenged the aristocratic establishment that ruled from time immemorial*". Highly critical of these studies aiming at computing the static Smithian gains from international trade, Findlay and O'Rourke (2007) contended that *"comparative static models cannot, by definition, say anything about the impact of trade on growth (p.337) […] International trade was a key reason why the British Industrial Revolution was sustained (p.339) […] The success of the European Industrial Revolution is intimately connected with trade and overseas expansion (p.364)*". According to Palma (2015:2), the dynamic argument of foreign trade has pushed a number of scholars

[41] Harley however failed to take into account the impact of trade on preferences for foreign goods and work patterns (see e.g. Malthus, 1836; de Vries, 1994, 2008; Broda and Weinstein, 2006; Hersh and Voth, 2009; v.d. Heuvel and N.Meerkerk, 2014).

who were initially "revisionist", like O'Brien and Mokyr, to adopt a more nuanced position concerning the role of trade openness in British industrialization. "*The reason for this shift in thinking is that there may be indirect, dynamic general equilibrium and spillover effect gains from trading*". Thus, although still in disagreement with the notion that trade can take credit for the British industrial revolution[42], Mokyr (2010a) however recognized that *"the openness of the economy was an important part of the story*". On the contrary, in *Bourgeois Dignity and liberty*, McCloskey (2010a) still recently considered that the logic of trade-as-an-engine was dubious and that even the dynamic effects of trade were small[43]. Rejecting foreign trade as the cause of the British industrial revolution, McCloskey (2010a) finally concluded: "*Trade is anyway too old and too widespread to explain a uniquely European – even British – event*".

f) Institutional and political factors

The role of the institutional and political environment has also been the object of growing interest in the literature. Thus, according to some scholars, the reason why the industrial revolution started in Britain is because the country had the "right institutions", notably the right political institutions. The idea that institutions matter for economic development has reflected a rising consensus in the economic literature (see e.g. North, 1989, 1990; Nelson and Sampat, 2001; Rodrik et al., 2004; Dixit, 2004, 2009; Dam, 2005; Acemoglu et al., 2005a; Greif, 2006a, 2006b; Helpman, 2008; Nelson, 2008; North et al., 2009; Acemoglu and Robinson, 2012; Ogilvie and Carus, 2014; Galiani and Sened, 2014; Fosu, 2015; compare Glaeser et al., 2004). In line with this institutionalist literature, a large number of historians have located the roots of the British industrial revolution into the "Glorious Revolution", also called the "bloodless revolution", which broke out in England in 1688 and finally led to the adoption of the *Bill of Rights* (1689) just ten years after the *Habeas Corpus Act* (1679) (see e.g. North and Weingast 1989; Acemoglu and Robinson, 2012). As Acemoglu and Robinson (2012:4) wrote, "*the reason that Britain is richer than Egypt is because in 1688, Britain (or England to be exact) had a revolution that transformed the politics and thus the economics of the nation*". The Glorious Revolution indeed marked the starting point of a quite long period of relative peace and political stability on the British territory[44]. This political event moreover supposedly contributed to create a business environment conducive to entrepreneurship, especially by consolidating the parliamentary monarchy, limiting the power of the King and

[42] For instance, Mokyr (2010) - as well as several other scholars (see e.g. Meisenzahl et al., 2012; Humphries, 2013a; Kelly et al., 2014) - rejected Allen (2009b,2010)'s theory of an induced industrial revolution, i.e. an industrial revolution induced by Britain's factor prices (high wages and low energy costs), which supposedly were the consequence of Britain's participation in trade. See Crafts (2011) for a parallel discussion of the two theories developed by Allen (2009b, 2010) and Mokyr (2010).

[43] See the Chapters 18 and 19 of McCloskey (2010a)'s book.

[44] In a recent book, Rosenthal and Wong (2011) also used this line of argument, among others, to explain why the industrial revolution first took place in England, and not in Continental Europe.

the action of the government, as well as reinforcing the property rights and contracting institutions. The new regime, headed by the Protestants William III of Orange and Mary II of England, also adopted new financial institutions, some had been previously developed on the Continent, and allowed the creation of the first national bank, namely the *Governor and Company of the bank of England*, which provided the public sector with lots of money, a large part of which was used to finance the development of the Royal Navy that became the "Master of the oceans", thus helping British expansion in foreign trade (O'Brien, 1998, 2005 and 2011). North and Weingast (1989) directly attributed the rise of the modern public credit in 18th century England - and the financial revolution - to the establishment of a new Constitutional monarchy which defended creditors' property rights against the exercise of arbitrary state power. According to O'Brien (1991), the British authorities increasingly grew in favor of property and against customary rights all over the 18th century. This evolution, which highly contrasted with the situation in most of Europe, especially during the French Revolution, supposedly led to a more efficient economic organization in Britain, i.e. a better allocation of resources, and spurred economic growth (see e.g. De Soto, 1989; Milgrom and Roberts, 1992; Bogart and Richardson, 2008; Besley and Ghatak, 2010; Kishtainy, 2011) (Ogilvie and Carus, 2014). A number of institutionalist scholars, especially those inspired by North (1981, 1990)'s works, have also argued that property rights, including the intellectual property rights, stimulated the creativity of British inventors and so contributed to raise the rate of innovative activity in Britain. The early existence of a British patent system - enacted as soon as 1624 in the Statute of Monopolies - would then account for the early emergence of market-oriented technical inventions on the British ground (see e.g. North and Thomas, 1973; Dutton, 1984; Sullivan, 1989, 1990). As North and Thomas (1973:155-156) contended: "*Innovation will be encouraged by modifying the institutional environment, so that the private rate of return approaches the social rate of return. Prizes and awards provide incentives for specific inventions, but do not provide a legal basis for ownership of intellectual property. The development of patent laws provides such protection […] By 1700 England had begun to protect private property in knowledge with its patent law. The stage was now set for the industrial revolution*". The argument linking the British patent system with the British industrial revolution has been empirically funded on data showing an uprising in patenting activity during the second half of 18th century Britain (see e.g. Dutton, 1984; Mitchell, 1988; Sullivan, 1989; Zukerfeld, 2014). Besides the intellectual property rights, including the patent law, some historians have also emphasized the relatively high degree of Britain's tolerance to explain why the country became a fertile ground for new ideas and inventions (see e.g. Braudel, 1982; Landes, 1983, Crouzet, 1991). As Mokyr (1999:38) argued, "*British society exhibited a degree of tolerance for deviant and heterodox ideas that was unusual, though not unique […] Britain developed in the 17th century the ability to accommodate a high level of acceptance of different modes of thinking. The intolerance on the Continent toward dissidents led to the hemorrhage of technical talents from the southern Netherlands and France to countries where they were more welcome*". Thus, the Calvinist Denis Papin, who anticipated the revocation of the Edict of Nantes, fled France in 1675 and joined London

where he worked in collaboration with Robert Boyle, well-known figure of the Royal Society, and invented the steam digester, one of the first steps toward the steam engine. Following Weber (1905)'s work, a link has even been established in the literature between religion and economic progress (see e.g. Landes, 1998; Becker and Woessmann, 2009; de Pleijt and van Zanden, 2013; compare Delacroix and Nielsen, 2001; Barro and McCleary, 2003; Cantoni, 2015). The non-renewal of the licensing Act in 1695, which was first adopted in 1662 after the restoration of King Charles II of England, is another illustration of Britain's tolerance. By taking this decision, the British Parliament paved the way to press freedom and the free circulation of ideas (Aspinall, 1948; Black, 1987). In the wake of this political decision, several newspapers saw the light of day, some were directly created by Protestant immigrates. The supposed achievements of the Glorious Revolution, in terms of promoting the private and individual initiative, i.e. the entrepreneurial spirit viewed by Rostow (1960) as a necessary precondition for take-off[45], were echoed by the new liberal economic thought that gradually gained in power and influence in the 18th century. This intellectual current was embodied by scholars such as Hume and Smith, and dubbed by metaphysicians such as Kant, Herder and Bentham. In *Political Discourses*, Hume (1752) thus advocated in favor of free trade and the international division of labor. In *An inquiry into the nature and causes of the wealth of nations,* Smith (1776) objected to the direct intervention of the State into the economy and promoted a laissez-faire policy in accordance with the idea of self-regulatory market forces.

Although attractive, the idea of an industrial revolution rooted into the Glorious Revolution has been strongly challenged in the literature. While acknowledging the importance of the institutional and political environment for economic development, some scholars have for instance pointed out the absence of discontinuity in institutions and growth in England after 1688. The Glorious Revolution and the Bill of Rights reaffirmed - although it truly enhanced (Bogart and Richardson, 2011) - a longstanding tradition of parliamentary controls over the executive (see e.g. Harrison, 1990; Hartley, 1992; Hoyle, 1994; Braddick, 1994; Goldsworthy, 1999; Allen, 2003; Clark, 2007a) (Ogilvie and Carus, 2014). More accurately seen as part of an evolutionary process of institutional development, the Glorious revolution moreover did not produce any acceleration of economic growth (see e.g. Van Zanden, 2001; Murrell 2009; Maddison, 2010 Broadberry et al., 2015) and so can hardly be credited for the industrial revolution that will occur almost one century later (Clark, 2014). Most analyses of financial statistics have also failed to detect significant improvements in the business environment or investment climate after 1688 (see e.g. Clark, 1996; Epstein, 2000; Quinn, 2001; Stasavage, 2002; Sussman and Yafeh, 2006) (Allen, 2006). The absence of such kinds of discontinuity seemingly gives support to scholars (e.g. Mokyr, 1999; O'Brien, 2001; Harris, 2004; Clark, 2007a; McCloskey, 2010a) who have strongly contested the belief that the British contracts and property rights, including those for state creditors, were insecure before the English

[45] See Mokyr (2010b, 2013b) for rich discussions on the debated role (dilemma) of entrepreneurship in promoting both the industrial revolution in Britain and modern economic growth.

Glorious revolution. A question so arises: what are the origins of British proper rights? In the tradition of the soft institutionalists who tend to attribute institutional changes to economic factors[46], Cordoba (2007:4) for instance contended that the set of economic opportunities offered by the Great Discoveries were responsible for the institutional changes that provided the proper incentives and rights to the British citizens: "*the nature of the new economic opportunities opened to Britain by the Great Discoveries empowered common citizens, created an entrepreneurial base, and was conductive to a weaker monarchy that eventually lost power to other forces represented in the Parliament*". This idea was already present in Acemoglu et al. (2005b:546)'s previous influential work: "*where "initial" political institutions (those established before 1500) placed significant checks on the monarchy, the growth of Atlantic trade strengthened merchant groups by constraining the power of the monarchy, and helped merchants obtain changes in institutions to protect property rights. These changes were central to subsequent economic growth*". In the quest for the deep origins of the institutions conducive to economic prosperity, van Zanden (2002, 2008) recommended going further back in history and called for a "revolt of the medievalists". Independently from the debate on the origins of the supposedly "good" British institutions, it has very often been defended that the latter were in any case not peculiar to Britain. For instance, other European regions such as the Dutch Republic and Venice also had parliamentary institutions exercising some degree of control over the government. With respect to the property rights, Allen (2003) noted that "*property was secure in all the leading European countries, whatever their constitution"*, thus joining other scholar's conclusions for specific countries such as the Dutch Republic (see e.g. Mokyr, 1999; Ogilvie and Carus, 2014) and France (see e.g. Hoffman et al., 2000). Contrary to North and Weingast (1989)'s claims, a number of scholars have even argued that the restrictions on private property rights did increase in England after the Glorious Revolution, contributing to prepare the industrial revolution (see e.g. Harris, 2004; Hoppit, 2011; Allen, 2011). Attempting to solve these apparently conflictual views, Ogilvie and Carus (2014:447) stressed the necessity to make the distinction between generalized and particularized property rights: "*The type of property right that is good for growth is a generalized right […] The property rights that were restricted in 18th-century England, by contrast, were largely particularized ones, which restricted use, transfers, and contracts involving assets to a limited subset of economic agents, who were defined at least partly according to non-economic criteria".* This potentially explains the reason why some scholars have sometimes argued that France actually suffered from too secure property rights (see e.g. Rosenthal 1990; Innes, 1992, 1998; Hoppit et al., 1994).

Concerning more specifically the intellectual property rights, scholars have long noted the difficulty to assess the exact role of the patent system in the British industrial revolution (see e.g. MacLeod, 2002; MacLeod and Nuvolari, 2006; Mokyr, 2009), especially as the results are

[46] By contrast, the "hard" institutionalists consider that the institutions are exogenous to the economy. See Abramson and Boix (2014) for a short critical review of the institutionalist theories aiming at explaining growth.

critically dependent on the reliability of the patent data as indicators of innovation (see e.g. Griliches, 1990; O'Brien and al., 1995, 1996; Nuvolari, 2004; Moser, 2005, 2012; Nuvolari and Tartari, 2011). If there seems to be a consensus on the idea that the rapid growth of British patents from the 1760s truly witnessed an upsurge of technological activity in Britain, it is not clear whether the patent law, as it existed, played a great incentive role in the processes that eventually brought about sustained economic growth (Mokyr, 2009). Before the reform of 1852, taking out a patent in Britain was expensive and time-consuming (see e.g. Harrison, 2006). Moreover, it was common for patents to be infringed upon, and judges, at least prior to 1825, were rarely friendly to the patent holders, seeing them as monopolists (see e.g. Robinson, 1972)[47]. As Mokyr (2009:351) noted, "*some of the most eminent men of science and technology in the period condemned the system as it existed […] It is striking that many of the important inventors of the Industrial Revolution viewed the patent system negatively and chose not to use it […] Many of the great engineers of the Industrial Revolution, Watt* and Arkwrigt *being the great exceptions, had little interest in patenting*" (see also Dutton, 1984; McLeod, 1988, 2009; McLeod and Nuvolari, 2010; Moser, 2007, 2012). O Grada (2014a:9) thus observed that "*most of British goods and processes on show at the Great Exhibition of 1851 had been developed without a patent*". The patent was only one way of protecting and rewarding an invention. In many cases, secrecy turned out to be considered as a better solution. Using a sample of 759 high-skilled mechanics and engineers, Meisenzahl and Mokyr (2012) concluded that these workmen largely relied on secrecy and first-mover advantages to reap the benefits of their technological inventions. Financial rewards were also provided by some public institutions like the Royal Society. In England, the parliament rewarded inventors for socially valuable inventions. By way of illustration, the fathers of the mule and the power loom, respectively Samuel Crompton and Edmund Cartwright, were part of the beneficiaries of this political rewarding system. In any event, all inventors were not first and foremost motivated by the desire to maximize their income. Honor and social recognition were other possible incentives (Mokyr, 2009). Assessing the appropriability argument, Clark (2014:18) noted that "*the industrial revolution economy was spectacularly bad at rewarding innovation*", and finally reached the conclusion that "*there is no evidence that it was institutional changes providing better rewards for innovators in the Industrial Revolution era that unleashed mankind's creative potential*". In the same vein, MacLeod (1988) argued that patents were more closely associated to the phenomenon of "emergent capitalism" than "inventiveness". Also very doubtful about the role of the British patent law, O Grada (2014a:9) claimed that "*Britain achieved and maintained technological leadership until mid-19th century with little resort to patents*". In a book entitled *against intellectual monopoly*, Boldrin and Levine (2008) even went as far as to say that "*intellectual monopoly was not necessary for innovation and as a practical matter was damaging to growth, prosperity and liberty*"[48]. Without questioning the potential incentive role of the patent law,

[47] Cited in Mokyr (2009).

[48] Boldrin and Levine (2008:2-3) introduced their research question in the following terms: "*In most histories, James Watt is a heroic inventor, responsible for the beginning of the industrial revolution. The facts suggest an*

Mokyr (2009:354) paradoxically suggested that the English economy might have benefited from the failures of the English patent law: "*had the system been more open and accessible, and had patents been more enforced, blocking patents and monopolies in rapidly changing industries may have slowed down the pace of progress. As it was, it may just have been enough to help keep Britain as the Workshop of the World until deep into the 19th century"*. In line with Mokyr's statement, Zuckerfeld (2014:16) also suggested that "*the complex and inefficient mechanisms of the English patent system played a simple and efficient role fostering - but not at all causing - the launch of the industrial revolution*". Convinced that economic theory cannot account for the growth of patents in the second half of the 18th century, Zukerfeld attributed the upsurge in patenting activity in Britain to the institutional changes which supposedly contributed to feeding the dreams of individual enrichment. "*Doing so, the* [inefficient] *patent system fostered both the innovative activity of individuals seeking rents and the social appropriation of the benefits of the innovations*".

The other appealing idea that the British public authorities, operating through strengthened democratic institutions, sought to design a general policy conducive to economic progress all over the 18th century, and the effects of which would have culminated with the industrial revolution, has also been seriously challenged in the literature. As Mokyr (1999:31) wrote: *any policy objective aimed deliberately at promoting long-run economic growth would be hard to find in Britain before and during the Industrial Revolution*. *To be sure, certain statutes aimed at encouraging progress […] But many of these acts were directed towards increasing the economic rents of a successful political lobby and their overall impact on technical progress at best ambiguous"*. The slave trade, the mercantilist regulations and the *Corn Laws*

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alternative interpretation. Watt is one of many clever inventors working to improve steam power in the second half of the eighteenth century. After getting one step ahead of the pack, he remained ahead not by superior innovation, but by superior exploitation of the legal system. The fact that his business partner was a wealthy man with strong connections in Parliament was not a minor help. Was Watt's patent a crucial incentive needed to trigger his inventive genius, as the traditional history suggests? Or did his use of the legal system to inhibit competition set back the industrial revolution by a decade or two? More broadly, are the two essential components of our current system of intellectual property – patents and copyrights – with all of their many faults, a necessary evil we must put up with to enjoy the fruits of invention and creativity? Or are they just unnecessary evils, the relics of an earlier time when governments routinely granted monopolies to favored courtiers? That is the question we seek to answer". And the authors finally concluded: "*Had there been no patent protection at all Boulton and Watt certainly would have been forced to follow a business policy quite different from that which they actually followed. Most of the firm's profits were derived from royalties on the use of engines rather than from the sale of manufactured engine components, and without patent protection the firm plainly could not have collected royalties. The alternative would have been to emphasize manufacturing and service activities as the principal source of profits, which in fact was the policy adopted when the expiration date of the patent for the separate condenser drew near in the late 1790s…. It is possible to conclude more definitely that the patent litigation activities of Boulton & Watt during the 1790s did not directly incite further technological progress…. Boulton and Watt's refusal to issue licenses allowing other engine makers to employ the separate-condenser principle clearly retarded the development and introduction of improvements.*

were all examples of economic policies maintained by the English parliament to defend the property rights and profits of powerful special-interest groups (Ogilvie and Carus, 2014). Thus, the Calico Act, which might have surprisingly favored the development of the British cotton industry (Mann and Wadsworth, 1931), was a protectionist measure passed in 1721 under the pressure of the silk and woolen industries. The experience of other European countries, such as Poland (see e.g. Kaminski, 1975; Frost, 2006; Guzowski, 2013), the Dutch Republic (see e.g. Mokyr, 1974, 1980; Buyst and Mokyr, 1990; de Vries and van der Woude, 1997; van Zanden and van Riel, 2004) and Prussia (see e.g. Brophy, 1995; Wheeler, 2011), also seemingly tends to show that the existence of powerful parliaments, exercising some control over the executive, was hardly enough to induce growth-friendly economic policies, especially when parliaments did not represent a diversity of views (Ogilvie and Carus, 2014). In these conditions, The advantage of Britain, where the State arguably did put into effect less harmful economic policies, and were less subject to the action of pressure groups (see Olson, 1982), was so less the existence of a powerful parliament than the absence, at least before 1800, of local authorities able or willing to enforce the supposedly harmful economic policies (Ogilvie and Carus, 2014). Even though lots of constraining rules and regulations still existed in legal books after 1688 and until deep into the 19th century, they were in fact often evaded with impunity (Mokyr, 1999). This situation contrasted with the extensive growth of state regulation in most European economies (Ogilvie, 1992, 1999; Ogilvie and Carus, 2014). As British economy became increasingly sophisticated, the local authorities, which actually proved to be little invasive in the economic field, were increasingly in charge of most internal administration. With the exception of international and colonial trade, which remained the object of great attention for the British Central State, Britain early had the characteristics of a decentralized “laissez-faire” economy (Mokyr, 1999).

Besides the ambiguous role of the English parliament in designing growth-friendly economic policies, other arguments have been advanced in the literature to contradict the notion that the British industrial revolution was produced or simply favored by the voluntary action of a State henceforth committed to the development of the whole British economy. For instance, O’Brien (1991) highlighted the numerous flaws and weaknesses of the English legal system that accordingly failed to provide efficient solutions to trade disagreements and commercial disputes. In this respect, Mokyr (2008) emphasized the informal private order institutions and “cultural beliefs” - as defined by Greif (1994, 2006b) - which supposedly substituted for the formal institutions to maintain a safe environment in which British entrepreneurs and innovators could operate and collaborate freely. Another point often brandished to discredit the role of the public authorities in British industrial revolution is the sharp increase in public revenues from taxation in England between the Glorious Revolution and 1815[49] (see e.g. Mathias and O’Brien, 1976, 1978; O’Brien, 1988 and 2001; Hoffman and Norberg 1994; Bonney 1999; McCloskey, 2010a). Over this period, real gross national income rose by three

[49] See Johnson and Koyama (2014) for a discussion on the origins of state capacity in England.

while real peacetime taxation increased by around fifteen (O'Brien, 2001). As Ogilvie and Carus (2014:458) noted: "*This huge increase in government control over national resources after 1688 casts serious doubt on the view that 1688 marked an improvement in the security of ownership rights of British taxpayers*". In principle, the improved state capacity for raising funds after the Glorious Revolution might have supported growth-friendly economic policies. But the British State rarely turned into public entrepreneur, and most of the projects which are nowadays financed collectively in regard to their positive externalities, like education, transport and the promotion of "useful arts" - that is applied science and technology -, were mainly left to private initiative (Mokyr, 1999). Public expenditures were primarily devoted to military purposes (O'Brien, 1988, 2001), notably to finance the wars against France whose impact on Britain's economy in the 18th century , although still debated, has been considered as negative and non-negligible by a number of scholars (see e.g. Williamson, 1987; Crafts, 1987; Mokyr, 1987)[50]. The Old Poor Law, another specific British institution, has also been heavily criticized, especially by Malthus and his followers, for its supposedly harmful effects on economic activity and technological change. It has long been believed that the poor relief system in England, which was seemingly generous (Ottaway, 2013) and well-developed in richer parishes and counties (Kelly and O Grada, 2011), encouraged excessive population growth, reduced labor supply through the alteration of the household trade-off between work and leisure, contributing to creating some unemployment trap, and hampered the professional and geographical mobility of labor in the context of a rising market society. However, the Old Poor Law might not have had its purported dramatic effects, particularly with regard to the population growth (see e.g. Huzel, 1969, 1980; Boyer, 1990; Kelly and O Grada, 2014a) and work incentives (see e.g. Pollard, 1978, Boyer, 1990). Moreover, the British poor relief system, viewed as a social risk-sharing institution, might have encouraged "risk-taking", thus contributing to bringing about a new class of successful entrepreneurs (see e.g. Greif et al., 2011; Greif and Iyigun, 2012, 2013). According to Solar (1995), it might also have contributed to building a new wage-labor force by cutting the vital rope that linked the rural population to land. Finally, Mokyr (1999) also highlighted the additional flexibility that the British Poor Laws might have provided to the British industry. The political action and the institutional environment surely had a great influence on one country's chance to undertake a successful industrialization (Bjorvatn and Coniglio, 2012; Vries, 2013). Designing a playing field considered as conducive to economic development is today the main goal of the industrial policy conducted by all Western governments. The secure property rights, the individual liberties, the political stability (see e.g. Olson, 1993, 2000) and the absence of important armed conflicts on the national ground were all elements that helped Britain's industrialization.

[50] Cited in Ogilvie and Carus (2014)

g) Modern science, technology, and human capital

Addressing the European aspect of economic development - *European miracle* - that led to the emergence of a "convergence club" at dawn of the 20th century, a number of scholars have stressed the role of modern science in producing the British and European industrial revolution (see e.g. Musson and Robinson, 1969, Jacob and Stewart, 2004; Bekar, Carlaw and Lipsey, 2005; Jacob, 1988, 1997, 2007, 2014). In line with this view, the industrial revolution would owe much to the European scientific revolution. Although broader in scope, the term "scientific revolution" is nowadays traditionally used to describe the changes in the scientific thought that progressively took place in Europe in the 16th and 17th centuries, leading all the scientific disciplines to reorganize around new principles/axioms (Cohen, 2010). The starting point of the scientific revolution is very often located in the Copernicus' heliocentric theory published in 1543 in a book entitled *On the Revolutions of the Heavenly Bodies* (Jacob, 1997). The Copernican model placed the Sun, not the Earth, at the center of the Solar system and so heretically broke with the geocentric astronomy and the canonized Aristotelian tradition that was widely taught at universities and had been elevated to the level of religious dogma through the influence of Christian scholastic philosophy. The revolutionary book, published at the end of Copernicus' life, set in motion a long series of works, notably by Galileo[51], and episodes that produced the scientific revolution in Europe and gradually substituted the Aristotelian system, which had been enriched and completed by savants like Ptolemy, Euclid, Hippocrates and Galen, with the modern view of astronomy and natural sciences. As from the scientific revolution, science started to take a different look on the world and modified its method of investigation. In particular, the mathematical tool and the experimentation gradually substituted for the barren metaphysical speculations (Marage, 2006). Renouncing, at least partly, the idealist heritage of Aristotle, science freed itself from a heavy burden and broke into modernity (Lenoble, 1943). Descartes (1637) thus discredited the speculative scholastic philosophy and presented a new method, greatly inspired from the mathematics, to produce knowledge and access certainty: "*Instead of the speculative philosophy usually taught in the schools, we may find a practical one through which we could know the power and actions of fire, water, air, the stars, the heavens, and all the other bodies in our environment, as distinctly as we know the various crafts of our artisans; and we could thereby employ these forces in the same fashion for all the uses for which it is appropriate, and thus make ourselves as masters and possessors of nature*"[52]. Descartes was convinced that the whole universe could be subject to a mathematical interpretation, thus joining in some way Galileo's conclusions, and that the natural phenomena could be explained by

[51] Armed with Copernicus' intuitions and astronomical instruments like the telescope, Galileo has often been credited with being the very first one to have, on one hand, undertaken the massive destruction of the physics derived from the Greek savants and, on the other hand, laid the foundations of the new modern science (Marage, 2006).

[52] "Discourses on the Method". In: Cottingham J., Murdoch D. and Stoothoff R. (eds.), *The Philosophical Writings of Descartes,* vol.1, Cambridge: Cambridge University Press (1985), p.142.

"mathematical reasons" operating in accordance with laws. In *the discourses on the method,* Descartes (1637) also introduced the early drafts of his famous philosophical proposition "*cogito, ergo sum*" he developed more precisely in two following books, namely *Meditations on first philosophy* (1641) and *Principles of philosophy* (1644), thus establishing the Cartesian metaphysical foundations of knowledge. The idea of mastering the nature was already well present in the work of Francis Bacon, often considered as one of the fathers of empiricism (Burns, 2001). Bacon violently rejected the scholastic interpretation of the classical texts and advocated in favor of an interpretation of the nature through both rigorous observation and theoretical reasoning based on new principles and deduction. As Bacon (1620) wrote: "*Those who have treated of the sciences have been either empirics or dogmatical. The former like ants only heap up and use their store, the latter like spiders spin out their own webs. The bee, a mean between both, extracts matter from the flowers of the garden and the field, but works and fashions it by its own effort. The true labor of philosophy resembles hers, for it neither relies entirely or principally on the powers of the mind, nor yet lays up in the memory the matter afforded by the experiments of natural history and mechanics in its raw state, but changes and works it in the understanding. We have good reason, therefore, to derive hope from a closer and purer alliance of these faculties (the experimental and rational) than has yet been attempted*"[53]. Bacon understood very early the complementary relationship that might link science and technology, i.e. theoretical knowledge and practical operation. He summed up the way to reach this complementarity by use of the following declaration: "*we cannot command nature except by obeying her*". As Newton defended the idea of a scientific method that would strictly match theory with experimentation, fulfilling Bacon's wish, this British scientist is nowadays often viewed as the savant who gave a completed form to the new science that eventually triumphed with the scientific revolution. Isaac Newton agreed with Descartes' refusal of the Aristotelian doctrine, but criticized the Cartesians as they did not sufficiently rely upon the experimental techniques promoted by Bacon and Boyle. In *the Mathematical Principles of Natural Philosophy*, Newton (1686) described the law of universal gravitation and rewrote the Kepler's three universal laws of motion, thus setting up the bases of classical mechanics. Newton's famous proposition "*Hypotheses non fingo*", through which Newton elevated to the highest scientific level the methodology aiming at discovering new mathematical relationships through the empirical observation of natural phenomena, was brandished as a principle by his successors and inspired generations of experimenters (Marage, 2006), especially those of the Royal Society*:* "*For whatever is not deduced from the phenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phenomena, and afterwards rendered general by induction. Thus it was that the impenetrability, the mobility, and impulsive force of bodies, and the laws of motion and of gravitation, were discovered"*[54]. Not

[53] "Novum Organum". In: Devey J. (ed.), *Novum Organum,* New York: P.F. Collier (1902), XCV

[54] *Isaac Newton's Philosophiae Naturalis Principia Mathematica*, in two volumes, Cambridge, Mass.: Harvard University Press (1972), II, pp.763-764.

solely astronomy but all the physical (electrophysics, thermal physics, etc.) and scientific disciplines benefited from the new scientific thought and made great progress during the scientific revolution and the subsequent 18th century Enlightenment. The new experimental science, equipped with revolutionary ideas, powerful mathematical tools and high-potential technical instruments, whose development was favored by the increasing recognition of the arts and crafts, progressively imposed itself as the most important source of explanation and domination of the world (Marage, 2006).

Regardless of whether Britain enjoyed scientific leadership on the eve of modern economic growth, there is an old discussion in the literature on the exact role of science in the British industrial revolution. Were the British technological inventions of the late 18th century and early 19th century the industrial and commercial products of the scientific revolution? Most of the debate actually developed around the argument formulated by Musson and Robinson (1969) that the British industrial revolution was not unrelated to the scientific revolution and required something more than the "uneducated empiricism" (p.87) suggested by traditional historiography[55] (O Grada, 2014a). Yet although some direct connection can be established between science and some of the industrial inventions, such as the chemical inventions and arguably the steam engine, scholars have found it hard to associate the main technological breakthroughs of the British industrial revolution with the scientific discoveries of its time (Mokyr, 2005b, 2011). Thus, a number of historians and economic historians have criticized Musson and Robinson's focus on science, arguing that early British inventions were mostly empirical and owed very little to direct scientific guidance and knowledge (see e.g. Mathias, 1972, McKendrick, 1973; Hall, 1974; Cookson, 1994; Mitch, 1999; Allen, 2009b; O Grada, 2014a). In parallel, some authors (see e.g. Gillispie, 1957) have stressed that the majority of the contemporary scientific advances were peripheral to industrial technology and so hardly subject, at least initially, to industrial application. At best case, science tried to provide the incumbent technologies with an implicit theoretical base (see e.g. Reynolds, 1983)[56]. As Mokyr (1999:50-51) noticed, "*in the development stage of the basic inventions, in which engineers and technicians on the shopfloor improved, modified, and debugged the revolutionary insights of inventors such as Cort, Cartwright, and Roberts to turn them into successful business propositions, pure science played only a modest role* […] If *science played a role in the Industrial Revolution, it was neither through the "pure" foundation of technology on scientific understanding nor through the role of scientists in invention but rather through the spillovers from the scientific endeavor*. In this respect, Mokyr (2000b) distinguished between three closely interrelated phenomena: scientific method, scientific mentality and scientific culture. Scientific method involves, among many others, accurate measurement, controlled experiment and the accumulation of "useful knowledge" (Mokyr, 2002) through activities of classification, reporting and cataloguing, whose importance was precociously

[55] See e.g. Mousnier (1958), Burstal (1963) and Daumas (1963).
[56] Cited in Mokyr (1999)

emphasized by the great philosopher and scientist Francis Bacon (see Yeo, 2003). Scientific mentality refers to the entrepreneurs' belief in the rationality and predictability of nature. Finally, scientific culture translates the entrepreneurs' confidence in the capacities of the new (applied) science to solve practical or technical problems and serve economic interests. According to Jacob (1988, 1997, 2007), science contributed to British economic success by designing the cultural and intellectual background for the British industrialists. In particular, British industry would owe a quite important debt to mechanical science and chemistry. In a book entitled *The first Knowledge Economy,* Jacob (2014) recently reaffirmed her position, arguing that the British industrial revolution resulted from the emergence of a new original class of entrepreneurs within a new industrial culture. By the mid-18th century, the British industry would have been increasingly penetrated by Newton's insights (Jacob and Stewart, 2004) and more generally modern science (Bekar and al., 2005). Goldstone (2006, 2009) attributed the British prosperity to the diffusion of the engineering culture - directly derived from Galileo's works on mechanics (Cardwell, 1972) - into the technological world of the production[57]. Shedding light on the culture of the Enlightenment, Mokyr (2005b, 2010a, 2011) proposed to explain British industrialization as a byproduct of the scientific revolution, that took a particular intellectual turn in the 18th century (Clark, 2012b). Mokyr (2005b:291) used the expression "Industrial Enlightenment", defined as "*the belief in the possibility and desirability of economic progress and growth through knowledge*", to describe the slice of the Enlightenment movement that supposedly bridged the scientific and industrial revolutions[58]. Providing a critical assessment of Mokyr's thought, Allen (2006:14) noted: "*the Industrial Enlightenment emphasized the application of the scientific and experimental methods to the study of technology, the belief in an orderly universe governed by natural laws that could be apprehended by the scientific method, and the expectation that the scientific study of natural world and technology would improve human life*". According to Mokyr, but also to several other scholars (see e.g. Goldstone, 2006, 2009; McCloskey, 2010a; Jacob, 2007, 2014; Meisenzahl and Mokyr, 2012), the British innovative entrepreneurs in the early stage of the British industrial revolution were to some extent the embodiments of the Enlightenment movement.

Yet, as Clark (2012b:89) contended, "*the industrial revolution was largely made not by the Philosophes in the Salons, or the professors in the Universities, but by Craftsmen with limited formal education solving basic technical problems*". This raises the following question: how did the culture that supposedly forged the link between science and industry disseminate into the economy? Addressing this question, Goldstone (2006, 2009) emphasized the importance of the social supports that arose in the 17th and 18th centuries and eventually made possible the combination of new approaches to knowledge and their commercial

[57] See also MacLeod and Nuvolari (2009)

[58] Mokyr (2005b) moreover contended that, without the Enlightenment, an industrial revolution could not have transformed itself into the sustained economic growth starting in the early 19th century.

application by private entrepreneurs. In the same vein, Mokyr (2005b, 2010a, 2011) shed light on the 18th century Enlightenment which supposedly carried out many aspects of the Baconian program through institutional developments that increased both the amount of knowledge and its accessibility to those who could make the best use of it[59]. These institutional changes, which rooted into the works of "cultural entrepreneurs" - as Mokyr (2013b) called them - like Francis Bacon and Isaac Newton, made Britain and Northwestern Europe more friendly to innovative activity. In this respect, Mokyr (2011) identified four different headings under which the application of the Baconian program allowed to increase the amount of "useful knowledge" – thus giving progressively access to more and more skill-biased technologies (O'Rourke et al., 2013) [60]. They are the research agenda, the capabilities such as the mathematics and the scientific instruments, the free selection of ideas, and their diffusion. Concerning the last point, the literature has proposed various channels through which the new scientific thought might have permeated the entrepreneurial culture. They include, among many others, the scientific societies like the Royal Society (funded in 1660), the publication of scientific books like the *Encyclopédie* and the "Newtonian textbooks", and the provincial scientific society meeting places, like coffeehouses and masonic lodges, where lectures on scientific subjects were organized. By raising the intellectual value of tolerance and liberty, the Enlightenment movement was per se favorable to the diffusion of new ideas in the society. Mokyr (2010a) thus highlighted the rise in the absolute and relative number of published books on scientific topics and technology over the period 1700-1800[6162]. Contemporary J.T. Desaguliers (1744)' writings interestingly report the development of a new "business of science" that consisted in marketing natural philosophy and mathematics. In Britain, the popular scientific lectures and the multiplication of the provincial scientific societies during the second half of the 18th century also seemingly revealed the growing connection between science and industry (see e.g. Thackray, 1974; Inkster, 1991). Greatly present in the northern regions of England and the Midlands, these societies were places at which industrialists, scientists, and enlightened philosophers met together and discussed. The Lunar Society of Birmingham was a famous example (see e.g. Schofield, 1957, 1963). It housed a lot of prestigious figures like the savant Joseph Priestley, the physician and botanist Jonathan Stokes, the natural philosopher Erasmus Darwin, the great industrialists Matthew Boulton and Josiah Wedgwood, and the inventor James Watt. Also member of the Lunar Society, the industrial chemist James Keir stated in his *Dictionary of Chemistry* (1789) that "*the diffusion of a general knowledge, and of a taste for science, over all classes of men, in*

[59] For instance, Dowey (2014) pointed out the dramatic rise of the learned societies in Britain between 1750 and 1850 as an important source of the decrease in the cost of access to knowledge.

[60] Persson (2010) recently considered that the European economic history before the industrial revolution was much less constrained by the population growth outstripping available resources than the lack of useful knowledge, defined as the limiting factor.

[61] See also Feather (1985) and Gardner (2013) for data on book publication in preindustrial/industrial England.

[62] A number of scholars have also incidentally emphasized the potential role of the press printing technology on literacy (see e.g. van Zanden, 2005b) and city growth (see e.g. Dittmar, 2011) during the preindustrial period as it cut the price of the books and seemingly was associated with high localized spillovers in human capital accumulation and technological change.

every nation of Europe, or of European origin, seems to be the characteristic feature of the present age". In sharp opposition to most cultural historians, Allen (2006, 2009b) yet refuted the idea that "high science", an activity reserved to a small elite, was responsible for the changes in the popular culture in Britain. In particular, Allen advocated against the idea that the provincial scientific society meeting places contributed - with truly a few exceptions - to spread scientific culture into the world of production. According to Allen (2006:15), these places were above all *"institutions at which science was talking to itself".* Quite In the same vein, O Grada (2014a) argued that the provincial scientific societies were exclusive and played only a limited role in disseminating scientific knowledge. Moreover, the commercial and manufacturing class would have rather seen such institutions as a stairway to social ascension (see e.g. Cardwell, 1970; Thackray, 1974; Cookson, 1994; Uglow, 2002; Jones, 2009)[63]. The belief that the typical innovative entrepreneur of the British industrialization was enlightened and, to some extent, connected to new science is actually far from being consensual in the literature. As Clark (2012b:90) contended, "*the Industrial Revolution was not about grand designs for social engineering, the distinctive focus of the Enlightenment, but about cheaper production of textiles, coal, iron and motive power. Most of the focus of the Enlightenment had little bearing on this"*. In his review of Mokyr (2010a)'s book entitled *The Enlightened Economy,* Clark (2012b) also highlighted the difficulty of distinguishing between the different idealist accounts of the British industrialization, especially between Mokyr's "Industrial Enlightenment" and McCloskey (2010a)'s "Bourgeois Revaluation". McCloskey (2010a) indeed defended, in line with Perkin (1969)'s pioneer work, that the enhanced social status for entrepreneurs played a great role in British economic success, which appeared in what North et al. (2009) have called an "open access society". *"How much is the Industrial Revolution the product of enhanced rationality, as opposed to just enhanced social status for entrepreneurs and the activities they had always carried out?"* (Clark, 2012b:90). As an attempt to characterize the "typical" inventor of the British industrial revolution, Allen (2009b) has recently produced a database of eighty high-profile inventors. Among them, about one half had enlightenment connections. In the area of textile, a sector which contributed significantly to productivity growth during the industrial revolution (see e.g. Harley, 1993; Clark, 2007a, 2014), Allen yet observed that most important inventors had little or no connection to the Enlightenment. Doing the same kind of exercise, Meisenzahl and Mokyr (2012) found that less than one-fourth of the 759 listed "British tweakers and implementers" had any schooling other than an apprenticeship, while only one in seven was a member of a scientific society like the Manchester Lit and Phil (cited in O Grada, 2014). They also observed that skilled workmen were seemingly affected by the new Enlightenment culture as they often published their work and engaged in debates over contemporary technological and social questions.

[63] Cited in O Grada (2014)

The proponents of the view that science made great contribution to the British industrial revolution have in fact increasingly used the argument that most of the foremost industrial inventors were not "untutored", as it has long been thought, but "educated" and equipped with scientific knowledge and intuitions, which supposedly fed their technological creativity and comparative advantage in producing inventions, and particularly microinventions. In this respect, some scholars have argued that one possible advantage for Britain - compared with France - was that British science was more pragmatic and applied (e.g. Kuhn, 1977; Inkster, 1991, Jacob, 1988, 1997). Concerning the entrepreneurs' education, Musson and Robinson (1969:88) noted: "*In recent years historians of education have done much to illuminate this question and their findings have suggested that a knowledge of science was more widely diffused through industrial society than has hitherto been suspected*". In agreement with this statement, Jacob (2007) used the expression "hybrid savant-technologists" to describe the entrepreneurs of Leeds whose workshop arguably was a place where science interconnected with technology. As Jacob (2007:198) wrote: "*In the critical first generation of mechanization that began in the 1780s, linen and wool manufacturers in Leeds, like their counterparts in Manchester, deployed scientific knowledge of a mechanical sort - and chemistry - to assist in the invention of new industrial processes and forms of industrial life".* Although convinced that science played a crucial role in the British industrial revolution, Jacob (2014) yet recently confessed that how scientific knowledge was acquired and diffused within British industry remained a mystery. The debate on the level of scientific knowledge deployed by British inventors has actually been part of a larger debate on the role of human capital in the British industrial revolution. If the current literature widely emphasizes human capital as one of the most important determinants of both economic growth[64] and per capita income[65], the exact role of human capital in the British industrial revolution is still very controversial. Observing, among others, a rise in literacy[66] and numeracy rates in pre-industrial Britain[67], a number of scholars have stressed human capital as a candidate source of the industrial revolution (see e.g. Tamura, 2002; Galor and Moav, 2004; Becker et al., 2011; Kelly et al., 2014; Madsen and Murtin, 2015). Yet international comparisons have shown that Britain actually did not enjoy any leadership in literacy and numeracy on the eve and during its industrial revolution. As Clark (2014:237) wrote: "*Literacy rates in England in 1780 were not high by the standards of many other parts of northwest Europe*. *Literacy rates then exceeded those of England in Scotland, the Netherlands, much of Germany and in Scandinavia".* Around 1800, literacy rates amounted to approximatively 60% for British males and 40% for females. It was slightly better than France, but worse than the Netherlands and Germany (Reis, 2005:202). Contrary to Stone (1969)'s findings, several studies have even evidenced a stagnation or decrease of

[64] See e.g. Barro (1991, 2001), Mankiw et al. (1992), Cohen and Soto (2007), Hanushek and Woessmann (2008), Casey and Watson (2013).

[65] See e.g. Hall and Jones (1999), Glaeser et al. (2004), Bhattacharyya (2009), Gennaioli et al. (2013) and Acemoglu et al. (2014).

[66] See e.g. Stephens (1990) and Houston (2002)

[67] See Hippe (2012) for a discussion on the complementary relationship between numeracy and literacy, two widely-used indicators of human capital.

literacy in England, at least in some industrializing districts such as Lancashire and Cheshire, during the industrial revolution period (see e.g. Sanderson, 1972; Schofield, 1973; Laqueur, 1974; Cressy, 1980)[68], thus giving credit to the "deskilling hypothesis" which supports the ideas that the industrial revolution raised the demand for unskilled workers and that human capital accumulation cannot account for British economic progress before 1850 (see e.g. Nicholas and Nicholas, 1992; Goldin and Katz, 1998; Mitch, 1999, 2004; Kirby, 2005; Humphries, 2010, 2013b; de Pleijt and Weisdorf, 2015). As Sanderson (2013:31) however said: "*Those who still regard education as important could fairly point to the rise in literacy between the 1690s and the 1760s as establishing a threshold for industrialization, whatever dip ensued subsequently".* In any event, it is by now widely accepted that Britain did not enjoy any advantage in schooling or formal institutions that provided human capital on the eve of and during its industrial revolution (Mokyr, 2013a). In agreement with this view, Galor (2005:194, 2011:30) declared: "*In the first phase of the industrial revolution, human capital had a limited role in the production process. Education was motivated by a variety of reasons, such as religion, enlightenment, social control, moral conformity, sociopolitical stability, social and national cohesion, and military efficiency. The extensiveness of public education was therefore not necessarily correlated with industrial development and it differed across countries due to political, cultural, social, historical and institutional factors".* Based on a sample of 7459 British mechanics and engineers, Meisenzahl and Mokyr (2012) also found that formal education played only a minor role in stimulating inventive activity during the British industrial revolution, thus supporting Mitch (1999)'s view that educational standards were low in Britain and inessential for economic development. Quite in the same vein, McCloskey (2010a:162) recently contended that human capital by itself had only little effect: a miner at the coal face may have to be skilled, but the hewer's skill had nothing to do with formal education and book learning. The same was true for skilled textile workers, construction laborers, sailors, etc. (cited in Mokyr, 2013a). Attempting to rehabilitate human capital as a key factor for the British industrialization, a number of scholars have been highly critical of the studies that only use aggregate data on education or literacy rates to assess the level of human capital of the average worker in the economy, stressing the role that the British engineers and entrepreneurs at the top of the skill or knowledge distribution might have played (see e.g. Mokyr, 2005a, 2010a; Kelly et al., 2014; Squicciarini and Voigtlander, 2014; van der Beek, 2014). As Mokyr and Voth (2009:5) noticed: "*The British Industrial Revolution was carried not by the skills of the average or modal worker, but by the ingenuity and technical ability of a minority*". In this respect, the literature has increasingly devoted attention on British education "outside the schools", notably shedding light on the potential importance of the British apprenticeship system as a means of transmitting knowledge, like tinkering abilities (McCloskey, 2010a) and the mysteries and secrets of trade (Farr, 2000), compensating for the flaws of the scientific texts and patents in disseminating technological knowledge (Epstein, 2004), and substituting for the learned societies and formal educational institutes (see e.g. Epstein, 1998; Humphries, 2003, 2011; Mokyr, 2010a, 2013a; Meisenzahl

[68] See Lemire (2013) for a historiographical survey of literacy in Britain between 1780 and 1830.

and Mokyr, 2012; Minns and Wallis, 2012). Long viewed as an hindrance to innovation, the British apprenticeship system might actually have helped human capital formation and thus spurred technological change, especially as it was relatively open and accessible (see e.g. Mitch, 2004; Leunig et al. 2011; Minns and Wallis, 2013), flexible (see e.g. Wallis, 2008), and not as restrictive as in other European nations like France (see e.g. Kaplan, 1993; Crowston, 2005). Thus, O Grada (2014a:8) recently contended that "*most of the foremost inventor-entrepreneurs of the Industrial Revolution were of rather modest, artisanal origins […] The artisans-made-good were the most talented and ambitious products of a system that combined basic schooling in literacy and arithmetic with apprenticeships based mainly on learning-by-doing*". According to Meisenzahl and Mokyr (2012), Britain's technological lead on the eve and during the first industrial revolution[69] was based upon "*the supply of highly skilled, mechanically able craftsmen who were able to adapt, implement, improve, and tweak new technologies and who provided the microinventions necessary to make macroinventions highly productive and remunerative*". Britain's advantage in terms of technological creativity would then owe a great deal to the British apprenticeship system which was the dominant form of skill formation at that time. Stressing the importance of the information exchange channels, like the British apprenticeship system, Abramson and Boix (2014) found in a recent study that "*economic growth was only possible when there was a population of craftsmen who embodied a given stock of technological know-how that enabled them to take advantage of the technological breakthroughs of the 18th-century*"[70]. The basic idea of this result is that worker skills facilitate technology adoption and so innovation[71]. This hypothesis is also present in other studies (e.g. Becker et al., 2011) which aim at showing that human capital facilitated the adoption of the new British industrial technologies in countries other than Britain in the 18th and 19th centuries. Another diffusion channel largely emphasized by the literature is the migration of British artisans and manufacturers, i.e. the migration of British skills, to other countries - for instance France (e.g. Henderson, 1954; Mathias, 1975; Harris, 1989). Besides the relatively important presence of highly skilled - in terms of ability and dexterity - mechanics and engineers in Britain on the eve of the industrial revolution, Kelly et al. (2014, 2015) also highlighted the physical condition of the average British worker as a crucial determinant of the quality of the British labor force. According to the authors, better nutrition made British workers healthier and taller, which can be viewed as a higher

[69] Britain's technological leadership on the eve of the industrial revolution has been contested by some scholars. For instance, Allen (2009b, 2010) has considered that this belief was largely biased by the fact that the industrial revolution first started in Britain. According to Allen (2009b, 2010), differences between countries in the profitability of doing R&D activities, determined in part by their access to foreign markets, would be more relevant to explain why the first industrial labor-saving inventions were British.

[70] In line with this result, Kelly, Mokyr and O Grada (2015) find in a recent study that "*English counties that were reliant on small scale industry, with the technical and entrepreneurial skills this generated, experienced the strongest industrial growth*".

[71] See e.g. Nelson and Phelps (1966), Benhabib and Spiegel (1994), Caselli and Coleman (2006) and Ciccone and Papaioannou (2009) for papers developing formally this idea.

degree of health human capital (see Schultz, 2002; Madsen, 2014), thus enhancing their cognitive ability and productivity, which might have spurred British industrial growth[72].

4. Conclusion

The British industrial revolution is still home to great mysteries. In particular, the causes of the British industrialization are still heatedly debated in the literature. As Clark (2012b:1) recently noted: "*The British Industrial Revolution is the key break in world history, the event that defines our lives. No episode is more important. Yet the timing, location, and cause of this Revolution are unsolved puzzles*". The difficulty partially arises from the fact that a broad spectrum of theories, both economic and non-economic ones, can potentially explain the industrial revolution and, more generally, the Great Divergence between some economically successful nations and the rest of the world. While this is hopeful, as it may be dangerous to overestimate the explanatory power of any single factor, the high multiplicity of possible theories has led Glaeser (2010b) to conclude that the industrial revolution would never be fully understood: "*While the reader craves a simple explanation, there is none to be had. The entire question of why the industrial revolution started in England will never be definitively answered. The event was sui generis a bolt of lightning; and there is a myriad of possible explanations for it. Some of those theories can be rejected, but many of them remain reasonable. The scholarly, if unsatisfying, path is to understand the details of the British Industrial Revolution and then judiciously to suggest which forces may have played a major role, and which theories are pure balderdash*". Every new reasonable theory inevitably adds complexity to the story of the industrial revolution, but also contributes doing better justice to the historical reality, deepening our understanding of that major economic event, which improves as we gather more reliable data and information on the empirics of the industrial revolution.

[72] See e.g. Jones and Schneider (2006) and Hanushek and Woessmann (2012)

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