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Economic growth before the Industrial Revolution: Rural production and guilds in the European Little Divergence☆

Mauro Rota [a], Luca Spinesi [b,*]

[a] Sapienza, University of Rome, Via del Castro Laurenziano, 9 00161 Rome, Italy
[b] University of Rome 3, Via Silvio d'Amico, 77 00145 Rome, Italy

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ABSTRACT

This paper explains how England became a high-income economy from the 15th to 18th centuries. The appropriate level of natural land suitability in the northern region of England before the Industrial Revolution was pivotal in weakening guilds' power and the diffusion of rural manufacturing. Unlike other European countries, those elements turned into a more efficient allocation of capital between cities and the rural areas and a more efficient shift of labor time from agriculture to manufacturing in the countryside, resulting in a higher income per capita by 1750.

1. Introduction

Divergences in income per capita are long-term persistent and still affect the hierarchy of economic development today; therefore, how history produced divergences is critical to understanding why some economies evolved precociously while others delayed the transition from Malthusian stagnation (Ashraf and Galor, 2011). We contribute to this broad debate by studying why England had already achieved the comparative advantages to start the Industrial Revolution before 1750.

England's prominent position before the Industrial Revolution took concrete form in its higher income per capita, which increased total factor productivity as a consequence of capital deepening (Voigtländer and Voth, 2006), permitted the adoption of the innovations of the early Industrial Revolution (Allen, 2009), and eased the demographic transition and the subsequent pattern of human capital accumulation (Galor and Weil, 2000; Galor and Moav, 2004). Kelly et al. (2014) argue that the higher labor productivity of English workers depending on better nutrition may have offset the higher wages, determining a unit labor cost lower than in France. Given the lack of definitive data regarding unit labor costs, significant evidence supports the notion of higher wages in England; thus, at the turn of the 18th century, England was a high-wage economy with the proper factor endowments for substituting expensive labor with cheap capital and energy (Allen, 2001).

This paper identifies the conditions that allowed England to be a high-wage economy before the Industrial Revolution. We argue that both the diffusion of manufacturing in the countryside and the relaxation of guilds' constraints to manufacturing mattered for the English success before 1750 from a European comparative perspective.

For this purpose, we present a dual model of city and countryside that historically emerged in Europe, particularly in England in the 15th century, which elucidates the changes for achieving the pre-conditions for embarking on the classical Industrial Revolution.

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* Corresponding author.
E-mail addresses: mauro.rota@uniroma1.it (M. Rota), luca.spinesi@uniroma3.it (L. Spinesi).

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Agricultural production conditions played a pivotal role in preparing for the Industrial Revolution. Kelly et al. (2015) compare English and French counties, documenting that the less favorable agricultural conditions in the early 18th century are good predictors of industrialization one hundred years later. The authors find that the ratio of small to large farms and the extent of existing industrial activity measured by the ratio of population to farmland were both present in the 18th century in rural areas where the Industrial Revolution began, which explains around two-thirds of the variation of industrial employment across England in the 1830s.[1] The type of soil, crops, and other climate conditions determined a different degree of industry spread in the countryside. To fix ideas, rice cultivation, common in Asia, required more time in this activity; however, it delivered higher returns per acre than wheat (Vollrath, 2011; Eberhardt and Vollrath, 2018). These contributions fix early industrialization and the transformation of rural areas as the pre-conditions for future growth and development. Allen (2009, p. 120) relates the spread of rural manufacturing to two forces that act in different directions. Increasing agricultural productivity discourages rural manufacturing, while enhancement in industrial productivity promotes its diffusion.

Our model integrates the pivotal role of agricultural productivity in the expansion of rural manufacturing. To accurately capture the dynamics at play, we account for the external factors that have consistently shaped productivity within the agricultural sector. One such influential factor, deeply rooted in history, is the undeniable impact of soil suitability.

In Europe, the mutual connections between cities and the countryside turned into a widespread production system that involved peasants in manufacturing. Since at least the 13th century, in some European regions, such as northern England, Flanders, and Normandy, merchants/entrepreneurs faced the incentive for decentralizing production in the countryside where labor was less expensive than in the guilded urban markets (Van Bavel, 2003; Horn, 2015; Hoogenboom et al., 2018; Ogilvie, 2019). Different views exist on whether guilds generated more benefits than harms or vice versa to the economic system of Europe between the 13th and the 18th centuries (Horn, 2015; Prak et al., 2020; Ogilvie, 2021); however, an inverse relationship between guild strength and economic performance has been found. Regions with weak guilds, such as Flanders and England, exhibited higher income levels and sustained growth than regions with stronger guilds. This relationship does not imply causation but highlights the diverse nature of guilds across European societies (Ogilvie, 2019, p. 559–563; Ogilvie, 2021). Moreover, it remarks how the link between guilds' strength and the diffusion of manufacturing production in rural areas can have played a role in achieving a higher income per capita and higher capital accumulation per capita in some European regions, such as northern England, where the Industrial Revolution started.

During the pre-industrial period, the shift of labor time from agriculture to manufacturing in English rural areas, part of a wider reallocation of household resources (De Vries, 1994), occurred in association with the decline in the power of guilds (Ogilvie, 2014). The role of guilds in the pre-industrial economy has been a subject of much debate. While evidence suggests that guilds promoted certain technological advancements (Epstein, 1998; De la Croix et al., 2018), they also operated as quasi-monopolistic institutions that extracted rents. The impact of city guilds in paving the way for the future Industrial Revolution through the use of skilled or unskilled workers before 1750 remains a matter of differing perspectives. Some argue that guilds played a critical role in disseminating productive knowledge and facilitating skills acquisition among European workers through apprenticeship and journeymanship (Epstein, 2013; De la Croix et al., 2018; Mokyr et al., 2019), contrasting with regions like China, India, and the Middle East where knowledge transmission relied more on extended families or clans. Others contend that intensified spatial competition in England during the 16th to 18th centuries led to the decline of guilds and the adoption of labor-saving technology (Desmet et al., 2020). This competition facilitated the diffusion of modern production technology employing unskilled workers, resulting in greater output per worker.

This paper shows that the interactions between city guilds and the hinterland countryside were essential to raising English income per capita by 1750. We study the pre-industrial economy using an overlapping generation model with endogenous fertility choices and capital bequests where each generation comprises two groups of individuals: workers and merchants/entrepreneurs. Workers live both in urban and rural areas. Workers living in rural areas endogenously allocate their labor time to agricultural and manufacturing activities, and workers living in cities are only employed in manufacturing production. Each merchant-entrepreneur can employ capital both in the countryside and in the city. We show that the endogenous allocation of labor time within rural areas and the endogenous allocation of capital between rural and urban areas increased the economy's chance to embark on the Industrial Revolution. In particular, as long as merchants/entrepreneurs earned an income flow higher than alternative productive activities (namely, workers' income), they had no incentive to break the rules on allocating resources imposed by guilds.

This inefficient equilibrium lasted as long as the cost of joining the guild system remained lower than the merchants/entrepreneurs' benefits. Once the merchants/entrepreneurs lost most of their advantages in participating in this inefficient equilibrium, they expanded the production in the countryside, triggering a process of Smithian growth, resulting in labor specialization without significant technological changes (Sokoloff and Dollar, 1997). In particular, once the income of merchants/entrepreneurs fell below that of the workers, they were forced to break down the constraints on the allocation of capital imposed by guilds and choose the efficient allocation of their capital between rural and urban areas. This situation, in turn, induced a shift of labor time from agricultural to manufacturing in the countryside, which, together with the shift in the allocation of capital between urban and rural areas, gave a strong impulse to the early stages of industrialization.

From the perspective of comparative development of Europe, the incentives for merchants/entrepreneurs to break the guilds' fetters varied across Europe, and bio-agricultural features played an essential role in shaping the behavior of pre-industrial economies. A large amount of evidence correlates the suitability of land, a natural exogenous element, to technology adoption and education (Galor and Özak, 2016), to trust (Litina, 2016), and to numeracy (Baten and Hippe, 2018). In our framework, land suitability correlates with the incentives for breaking the guild constraints. We adopt a land suitability definition that includes the suitability of soil for rain-fed crops and pasture (van Velthuizen, 2007). According to our model, in areas where land suitability was lower than in England, such as pre-industrial Italy or Spain, the propensity of peasants to sell their labor time in manufacturing was higher. Merchants/entrepreneurs could hire labor time at a lower wage and sustain their income. In this scenario, the merchants'/entrepreneurs' income was higher than the manufacturing wages paid in the rural and urban areas. As long as this condition held, merchants/entrepreneurs had no incentive to escape the guilds' control, and the economy remained trapped in a stagnating pattern. In contrast, higher land suitability, as in the Low Countries, reduced the peasants' willingness to spend time in manufacturing, reducing the incentives of merchants/entrepreneurs to expand production in the countryside. By reducing the possibility of exporting capital in the countryside, in tandem with the quasi-monopolistic behavior of guilds, the incomes of urban workers grew so fast that they got close to and even surpassed the merchants'/entrepreneurs' income. At that point, the incentives to break the guild constraints ripened, and merchants/entrepreneurs were free to move capital to the countryside, triggering Smithian growth but on a smaller scale and later than in England. In such a context, the total income per capita grew but at a lower rate than England, which therefore had a small but crucial advantage in increasing its probability of triggering the Industrial Revolution well before the Low Countries.

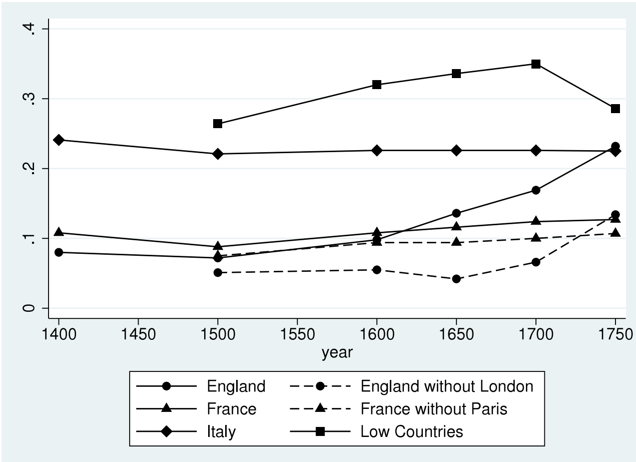


Fig. 1. Urbanization in Europe.
Source: Our computation is based on Allen (2000), p. 8–9). Data on London's population is from Wrigley (1987, p. 162), and Paris's population is from Bairoch et al. (1988). Note that urban population refers to people living in a city or town with more than 5000 inhabitants.

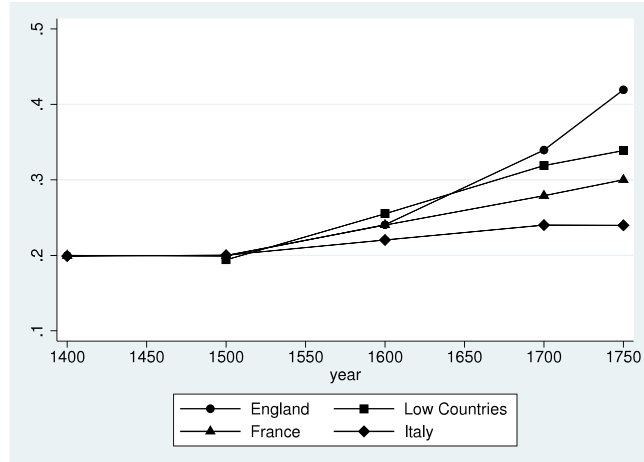


Fig. 2. Diffusion of manufacturing outside cities measured as a share of nonagricultural occupation in the countryside.
Source: Our computation on Allen (2000, pp. 8–9).

The flow chart presented in Appendix A.4 helps us understand our model's logic and its implications for the debate about the Little Divergence of Europe.

The remainder of the paper is as follows. Section 2 presents the historical background, while Section 3 develops the theoretical model, which is simulated in Section 4. Section 5 describes the simulated model's comparative static linking different scenarios to different historical pre-industrial economies, and Section 6 concludes.

2. The historical background

2.1. Urbanization

The process of industrialization has been linked to an agglomeration of resources and people in urban areas. In this respect, urbanization rates are often used to pinpoint the process of development in comparative studies or track countries' economic prosperity. The Industrial Revolution in England is also associated with the unprecedented growth of urban areas, especially London; however, there are two reasons why urbanization is unlikely to signal an underlying growth process, at least in England. First, most urbanization occurred in the late 18th century and the following decades when the classical Industrial Revolution was underway. The second reason calls into question the localization of the English Industrial Revolution. It is well-established that the early stages of the Industrial Revolution occurred in the North of England (Kelly et al., 2023), an area with very low urbanization. Thus, cities are not the only places to look at to understand the changes that led to the Industrial Revolution in the centuries preceding 1750. England had very low urbanization rates compared to other leading European countries, and the urban population growth occurred only in the late 18th century and was mainly driven by London (Fig. 1).

2.2. Rural manufacturing

Recent approaches have rediscovered the role of the countryside in preparing for the Industrial Revolution in England. Acquiring informal skills through manufacturing diffusion in some rural areas correlates with the technological changes that emerged after 1750 (Kelly et al., 2023). Furthermore, comparing England and France shows that rural areas experiencing a faster diffusion of manufacturing before 1750 are those where manufacturing spread widely in the 19th century, another promising area for industrialization (Kelly et al., 2015). However, the countryside was the theater of changes in household behavior in the mid-17th century, which De Vries (1994) labeled the "industrious revolution". More generally, the structural transformation of the English economy that began in the 17th century was facilitated by the inheritance of a developed system of rural protoindustry and commercial agriculture (Wallis et al., 2018). The reallocation of labor time from self-subsistence agriculture to manufacturing production promoted the Smithian growth that preceded the Industrial Revolution.

Peasants worked for merchants and entrepreneurs who found moving capital out of the cities profitable, where, in turn, manufacturing production was under the control of the guilds. This new type of organization of production outside the cities diffused everywhere across Europe, but substantial differences existed in both qualitative and quantitative terms across countries. The pattern of nonagricultural employees in rural areas documents the spread of manufacturing in the countryside (Fig. 2). Note that these numbers may not fully reflect the broader transformation of labor time allocation in the peasants' households to the extent that double occupations were the norm in the pre-industrial time and that nonagricultural occupations also included the service sector; however, in the early 17th century, England pulled away from the other countries, opening a gap in capital and the working time allocated to nonagricultural activities in the countryside. Manufacturing diffusion in rural areas was the combined effect of competing forces. It was decreasing in the labor productivity of agriculture, of which land suitability is an important determinant, and it was increasing in the labor productivity of the textile sector, of which capital deepening was a crucial factor (Allen, 2009, p. 120–121). Furthermore, institutional arrangements set by the guilds' system played a pivotal role. The following two subsections provide the details on factors influencing the spread of protoindustry and its characteristics at a sub-national level.

2.3. Guilds

In our model of the pre-industrial economy, the guilds are relevant for their links with the diffusion of manufacturing in the countryside.

During the Middle Ages, guilds organized themselves around economic interests and enjoyed legal privileges granting exclusive rights to practice specific occupations in designated areas. Because of their privileges, guilds exerted some power and coordination in both the input and output markets. Horn (2015), Hoogenboom et al. (2018), Ogilvie (2021, 2019). After 1500, guilds weakened in North–western

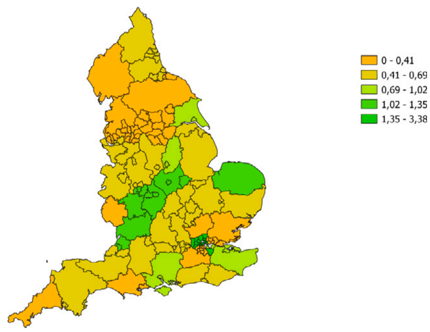


Fig. 3. Diffusion of apprenticeship in England around 1700.
Source: Our computation on Minns and Wallis (2013).

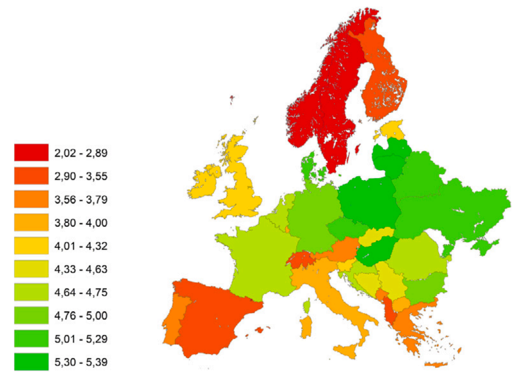


Fig. 4. European Land suitability for rain-fed crops and pasture.
Source: Our elaboration on van Velthuizen (2007).

Europe, including England, the Dutch Republic, Flanders, and, to a lesser extent, Normandy in France (Horn, 2015, chaps. 2–3; Hoogenboom et al., 2018; Ogilvie, 2019, p. 512–559), while experiencing a strengthening trend in Central, Central–Eastern, Northern, and Iberian Europe. Even if England, the Low Countries, and the northern region of France were exceptional in weakening guilds, some differences between these regions exist.

English guilds experienced a decline during the 16th century, with the crown dissolving religious and occupational guilds during the Reformation. Provincial guilds relied on local urban authorities, and their power waned in economically stagnant borough towns. Industrial towns like Manchester, Leeds, Birmingham, and Sheffield, where guilds had little influence, proliferated. Even in old corporate boroughs, guilds were in decline by 1650 (Harding, 2000; Ogilvie, 2019).[2]

The number of apprentices across English counties evolved over time, documenting the actual decline of Guilds. In London, the absolute number of apprentices peaked around 1675 and then declined in the following hundred years (Leunig et al., 2011). Given the population growth in London, the number of apprentices per head declined from 1625 to 1650. We see the same pattern in Yorkshire and Leicestershire (Fig. 3).

Arguably, the spatial competition between different cities in preindustrial economies prompted artisans to leave the guilds, and such competition was stronger in England than elsewhere (Desmet et al., 2020). Thus, the rise of manufacturing production in rural areas in England reflected the decline of guilds rather than the substitution of their power with other forms of monopolies, as in other areas of North-western Europe.

In the Low Countries, guilds formed alliances to gain political power and counter abuse by urban elites. The economic fluorescence of Flandres dates back to the 13th and 14th centuries when producers in the textile sector, particularly the linen industry, were independent farmers, often in possession of small farms and means of production that were relatively cheap. ; however, their possibilities were severely limited by the privileges and prerogatives of the cities. The oppression of rural manufacturing activities and the wide use of urban monopolies found partial support in the strong political position of cities (Van Bavel, 2003).

In Holland, urban privileges were relatively weak or not applied to the same extent as in Flanders; however, during the 14th and 15th centuries, peasants' performance of proto-industrial activities in Holland intensified only due to the increasing difficulties with arable farming, which forced peasants to find additional sources of income. Only those sectors that did not fall under manufacturing in the strict sense, such as fishing, shipping, and peat digging, flourished in the Holland countryside. From the late 14th century, these sectors witnessed an increasing capital intensity, a growing role of urban investors, and a deep proletarization. In the 16th century, as the investments by burghers seemed to have shifted more to landlords, peasant landownership was progressively replaced by large landownership, whereby the peasant element in nonagricultural activities started to disappear completely (Van Bavel, 2003). From the 17th century, guilds were present and exercised some political and economic role, but with different characteristics and dynamics across the regions of the Low Countries (Prak, 2006, p. 92, 95–99, 100–104).

Normandy implemented a system of spatial privileges more extensively than any other region in France (Horn, 2015, chap. 3). Divided into three generalities, Rouen, Caen, and Alençon, from at least the 13th century, Normandy became a highly industrialized province, with merchants transferring wool to rural areas for processing. However, in the textile sector of Normandy's rural areas, the guilds fixed wages, and employers were not allowed to increase them (Chambru and Maneuvrier-Hervieu, 2023, p. 6). In Flanders, rural work in the textile sector occurred under the privilege system that should be understood as the triumph of some privileges over others rather than the victory of freedom over the monopoly of business (Horn, 2015, p. 65–68).

2.4. Land suitability

In addition to endogenous variables, such as the density of urban settlements and intra-cities competition (Desmet et al., 2020), several exogenous factors were crucial in weakening guilds throughout Europe. These factors influenced the decline of guilds in various cases, including improved accessibility to rivers, the flatness of land, and, most importantly, the natural suitability of the land. These elements amplified the potential market access and fostered increased competition (Ogilvie, 2019). We refer to the natural suitability of land for raising crops and pastures. The FAO data provide a geographical distribution at a very detailed level (5 arc-minutes) of the current natural suitability of land. We use a composite index that accounts for the suitability of current land for nine rain-fed crops and pastures compiled by van Velthuizen (2007). Natural land suitability is a somewhat exogenous variable that describes how much agricultural output is potentially influenced by natural factors, excluding all other human factors that can influence agricultural productivity. In Fig. 4, we have represented the distribution of land suitability for Europe, showing a clear hierarchy in Western Europe.

Mediterranean Europe has a lower land suitability than the continental part, while England is an intermediate case. In particular, land suitability is comparatively lower for Spain and Italy, and France has relatively higher land suitability in Central Europe. In the map, we have represented present-day Belgium and the Netherlands in the same

[2] In England, although some guilds formally existed for specific trades, especially in London, their role was no longer the control of production or the exercise of their traditional prerogatives; they simply existed as trade associations without any specific power.

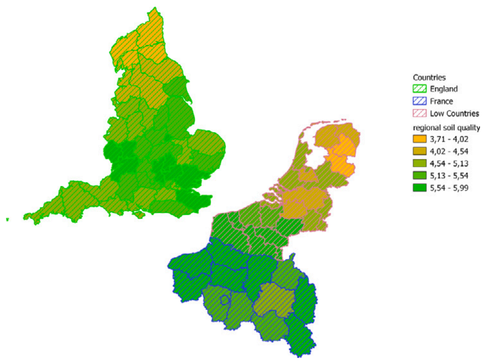


Fig. 5. Suitability for rain-fed crops and pasture in the North-western Europe.
Source: Our elaboration on van Velthuizen (2007).

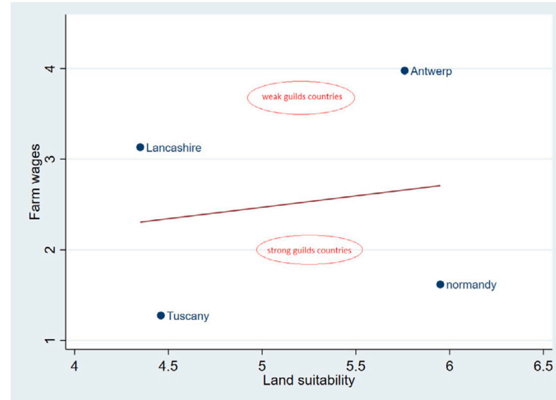


Fig. 6. Farm wages (around 1670), land suitability, and guilds strength in selected European regions.
Source: Our elaboration on van Velthuizen (2007) for land suitability. Wages are in silver deflated for one respectability basket. Lancashire wages are from Clark (2001) deflated by Allen's (2001) consumer price index (CPI). Antwerp wages are from De Pleijt and Van Zanden (2021), provided by the authors, deflated by Allen's (2001) CPI for Antwerp. Normandy wages are from Chambru and Maneuvrier-Hervieu (2023). For Tuscany, wages come from Rota and Weisdorf (2021).

geographical unit, which overlaps the Low Countries' historical region, which is commonly compared to England in the economic history literature (Allen, 2001). Germany is represented at its current boundaries but was not yet unified during our analysis. We have represented it in the map for completeness but excluded it from our comparative analysis because it still had several feudal traits, including serfdom. The use of the natural suitability index could be affected by two shortcomings discussed below. First, the index shows current land suitability, which might be unfit to describe past land suitability. The comparative historical analysis is interested in the rank of land suitability rather than in the actual measure of it. Thus, in line with the conventional use of the FAO data in comparative studies (Litina, 2016; Baten and Hippe, 2018), we assume that the rank has not changed much (Michalopoulos, 2012). The second issue deals with land suitability for pasture alongside crops. We believe grazing was essential to peasants' choices regarding allocating their labor time because livestock could graze unattended, leaving peasants more time for alternative uses.

National land characteristics may hide different soil suitability within the country, which is especially important in the case of England because the early start of the Industrial Revolution mainly occurred in its northern part. The following Fig. 5 clarifies two important stylized facts. First, Normandy and the Southern Low Countries exhibit higher soil suitability than the North of England. Second, the wealthiest part of the Low Countries, Holland, has a land suitability lower than Flanders but still moderately higher than the northern areas of England.

In our model, both the land suitability, via protoindustrialization, and the guild strength play a central role in explaining the advantages of England before the Industrial Revolution. We provide evidence in Fig. 6 that lower land suitability is associated with lower wages paid in agriculture, which pull peasants toward manufacturing. High-wage countries lay above the interpolating lines and are associated with a weak guilds system. The low-wage countries lay below the line and are associated with a robust guild system; thus, the positive relationship between farm wages and land suitability holds conditionally to the guild's strength, which determines the scope for capital accumulation in the countryside, whereby manufacturing productivity in rural areas is determined.

With the strength of guilds constant, we provide further evidence that agricultural wages are associated with lower land suitability. This confirmation is crucial to square the assumptions of our model in the geographical pattern of the Industrial Revolution that started in the North of England. Thus, we expect to find that the northern counties of England, the theater of the Industrial Revolution, have soil suitability lower than the southern part of the country. Moreover, as a companion of the different soil quality, we gathered data on farm wages broken down by counties. Clark (2001) compiled a winter wage series for farm laborers in four areas of the country (North, Midlands, South–West, and South–East). According to Clark's data, farm wages in the North were lower than in the Midlands and even lower than in southern macro-areas. In the 1670s, North farm wages were 64% of the average computed on the rest of the country. By 1740, they were 71%; thus, soil quality and farm wages seem positively correlated, implying that the model's assumption is rooted in historical evidence. North (and Midlands) farm wages departed from the rest of the country only after 1780 when the Industrial Revolution unfolded. A detailed representation of English soil suitability and farm wages is presented in Fig. 7 and confirms that the North had less scope for agricultural activity, including grazing, than the South.

A counterargument to our central hypothesis may be advanced in the light of the enclosures of open fields and villages' lands that occurred in pre-industrial England. By excluding peasants from the land, enclosures may have induced landless people to settle in areas with better soil quality or, more likely, to have led to a surplus of landless workers available for manufacturing. There were two waves of enclosures in England. The first occurred between 1550 and 1650, while the second, much more relevant, unfolded in 1750–1850. Apart from the magnitude of the enclosure movements, the striking difference between the first and second waves is that the earlier wave was mostly by voluntary agreement while the second wave was by parliamentary (Allen, 1992). It is unlikely that a voluntary agreement, with a complex system of land enclosing, brought about a substantial surplus of landless labor that provided the "reserve army of labor" to be employed in manufacturing.

Conversely, the expulsion of laborers from agriculture may have occurred when the enclosures freed labor by increasing agricultural productivity; however, agricultural productivity fluctuated during the first wave of enclosures, experiencing negligible changes compared to pre-enclosures (Allen, 2000). The big jump in agricultural productivity occurred immediately before the second wave. In conclusion, because of their size, mechanism, and effects, it is more likely that enclosures made rural labor free of agriculture only during the second wave rather than during the first wave, which is the historical period under investigation.

2.5. Technological progress before 1750

Europe's technological level lagged behind the advanced Asian civilizations at the beginning of the 13th century. During the pre-modern period, Europe witnessed incremental innovations in various sectors,

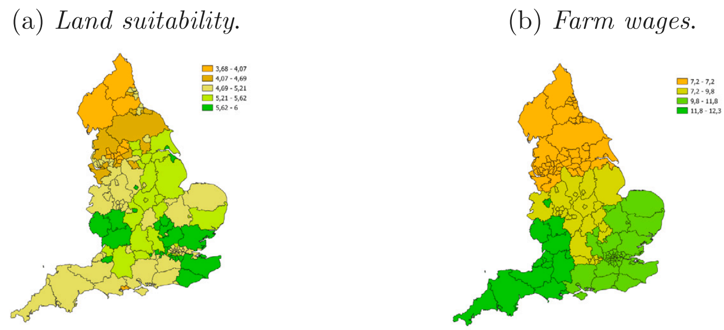


Fig. 7. Land suitability and farm wages within England around 1670.
Source: Our elaboration on Clark (2001) for wages and van Velthuizen (2007) for land suitability.

including metallurgy, instrument manufacturing, mining, construction, shipbuilding, chemical processes, and textile production (Epstein, 2013). Notably, Europe's progress was persistent and uninterrupted compared to India and China, which experienced periods of efflorescence lasting a few centuries, followed by long phases of stagnation. Innovative products introduced by the Europeans include the mechanical clock, gunpowder, glasses, and cast iron, while also adopting inventions from other civilizations, including paper, navigation tools, Arabic numerals, Latin sailing, and wind energy. However, it is challenging to argue that these inventions significantly affected gross domestic product (GDP) growth or aggregate output compared to other factors encompassed by the Smithian growth concept (Mokyr, 2005).

Moreover, despite these advancements, most of the workforce remained employed in agriculture, where progress was slow. During 800 CE and 1300 CE, Europe implemented the three-field system and improved cattle usage, resulting in notable productivity gains. Nonetheless, some technical innovations emerged in the agricultural sector in Europe between the 13th and 18th centuries. Water-powered mills became increasingly prevalent from the 13th century onward, enhancing grain processing efficiency and agricultural productivity (Mokyr et al., 2022). The introduction of the horse-drawn plow in the 14th century accelerated plowing, enabling farmers to cultivate more land. Crop rotation practices also emerged during this time, aiding in maintaining soil fertility and preventing depletion. Jethro Tull's invention of the seed drill in 1701 revolutionized planting by allowing farmers to plant seeds in straight lines, leading to improved crop yields and reduced labor costs. Other innovations included the development of new crop varieties, new animal breeds, and widespread fertilizer use; however, while revolutionary changes in English agriculture occurred during several periods spanning from 1560 to 1880, the English agricultural revolution occurred well after the 18th century (Clark, 1993; Overton, 1996).

The technical and practical knowledge of artisans and engineers in Europe and other regions primarily drove incremental innovations during the pre-modern period. These advancements were rooted in the expertise of experienced artisans (Mokyr, 2005; Epstein, 2013) in the early stages of industrialization when technical competence outweighed formal education and literacy; thus, early modern technical knowledge coincides with understanding how to make things and utilize them correctly (Mokyr, 2005; Epstein, 2013; Mokyr et al., 2022, 2019).

The knowledge diffusion depended on direct human interactions. Skilled individuals trained by guilds or other communities of specialized technicians, such as miners, builders, and shipbuilders, played a significant role in creating and diffusing new ideas and methods. Commercial relationships and migrations were the primary transfers of technology across societies. Historically, this shift occurred from Italy (1200–1450) to the southern Rhineland and the southern Netherlands (c.1450–1570), then to the Dutch Republic (1570–1675), and finally to Britain after around 1675 (Epstein, 2013). In the pre-modern economies, the relevant and decisive technical knowledge of artisans was embedded in the artisans themselves and moved with them.

In this context, British artisans, as a whole, exhibited superior quality during the Industrial Revolution (Kelly et al., 2014, 2015, 2023; Mokyr et al., 2022); however, while the technical skills of artisans were present across Britain, it is well-known that the concept of the Industrial Revolution began in Northern Britain. Manufacturing production shifted from urban centers in the eastern plains to the hilly rural districts of the north and west during the 13th and 14th centuries (Lucas, 2005). Indeed, Mokyr et al. (2022) argue that the rise of a community of millwrights and highly skilled mechanical craftsmen, in combination with specific geographical factors easing watermill location, favored the accumulation of valuable knowledge to exploit the opportunities of the Industrial Revolution in the 18th century.

Therefore, the determinants of the geographical location of production within Britain and the determinants of the location choices of individuals from the 13th century until 1750 should be explored to shed further light on the long march toward the Industrial Revolution. Given the above discussion on the nature of technical skills and knowledge before 1750, we assume no sensible technological change in agriculture and manufacturing during the period analyzed in this paper. In turn, we focus on allocating individuals' labor time between farming and manufacturing in rural areas and merchants' choice of capital allocation between city and countryside. In doing so, we use a one-good economy that allows us to concentrate on the locational aspects rather than on price mechanisms and terms of trade across food and manufacturing goods. In this set-up, technological change is irrelevant to capture the individuals' locational choice between sectors.

3. The model

We consider an overlapping-generations model with bequests, where individuals live for two periods. At each date $t \geq 0$ total population N_t is composed of two groups: workers (l_t) and merchants (m_t). Since the main focus is on the organization of the production process between rural areas and cities and within rural areas, a one-good economy is assumed; however, we use two different production functions: one for farming and one for manufacturing. In particular, the farm production process is only carried out in rural areas and requires labor and a nonaccumulative factor, i.e., land, while the manufacturing production process employs labor and an accumulative factor, i.e., capital. The manufacturing activity can take place both in towns and in the countryside. Each worker living in rural areas chooses the quantity of their labor time spent in both farms and manufacturing, while workers living in cities only supply their labor services in manufacturing. A merchant can employ capital both in rural and urban areas. Following the historical facts and because we are modeling a pre-industrial economy, we assume no substantial and sustained technological progress exists.

3.1. Preferences

In the first period of life, workers are born with a homogeneous and constant quantity of labor time endowment D, which is inelastically supplied, and receive no bequest. For the sake of notational simplicity, the labor time of each worker is normalized to one, i.e., $D = 1$. Merchants are assumed to own capital, receive capital bequests, and supply no labor services. Production takes one period to be completed. During their first period, each worker supplies the labor services, and each merchant employs the capital services. In the second period, individuals receive their income, choose their optimal level of consumption and offspring (net fertility), and merchants leave capital bequests. Considering the budget set, we assume that each individual i maximizes the utility function. When the income flow is below consumption at subsistence level $\bar{c}$, i.e., $y_{i,t} \le \bar{c}$, each individual consumes all income and obtains utility $u_i(c_{i,t+1}) = \left(c_{i,t+1}\right)^{\delta_i}$, where $\delta_i \in (0,1)$.

When the income flow of a worker, $l = r, u$, living either in rural (r) or urban (u) areas, born at any time $t \ge 0$, exceeds the subsistence level $\bar{c}$, the following maximization problem is solved:

$$\begin{gathered}\underset{c_{l,t+1},n_{l,t+1}}{Max} \left(c_{l,t+1}\right)^{\delta_l} \left(n_{l,t+1}\right)^{1-\delta_l} \\ \text{s.t. } c_{l,t+1} + \bar{c}\left(1+\theta n_{l,t+1}\right) = y_{l,t}, \text{ if } y_{l,t} > \bar{c}\end{gathered} \tag{1}$$

where $\delta_l \in (0,1)$. Furthermore, $c_{l,t+1}$ and $n_{l,t+1}$ are consumption and net fertility, respectively, $\bar{c}\theta > 0$ is the subsistence level for child-rising, and $y_{l,t}$ is the income flow of a worker $l = r, u$ born at any time $t \ge 0$. In light of such preferences, the optimal consumption and offspring choices are (see Appendix A1):

$$\begin{aligned} c_{l,t+1} &= \delta_l \left(y_{l,t} - \bar{c}\right) \\ n_{l,t+1} &= \tfrac{(1-\delta_l)}{\bar{c}\theta}\left(y_{l,t} - \bar{c}\right)\end{aligned} \tag{2}$$

Similarly, when the income flow of a merchant m born at any time $t \ge 0$ exceeds the subsistence level, the following maximization problem is solved:

$$\begin{gathered}\underset{c_{m,t+1},n_{m,t+1}}{Max} \left(c_{m,t+1}\right)^{\delta_m} \left(n_{m,t+1}\right)^{1-\delta_m} \\ \text{s.t. } c_{m,t+1} + \bar{c}\left(1+\theta n_{m,t+1}\right) = y_{m,t} \text{ if } y_{m,t} > \bar{c}\end{gathered} \tag{3}$$

where $\delta_m \in (0,1)$. Furthermore, $c_{m,t+1}$ is consumption, $n_{m,t+1}$ is the net fertility, and $y_{m,t}$ is the income flow of a merchant born at any time $t \ge 0$. Given the optimal net fertility choice $n_{m,t+1}$, total capital bequests are $k_{t+1} = n_{m,t+1}\tilde{k}_{t+1}$, with $\tilde{k}_{t+1}$ being the individual capital bequests. Notably, individual capital k_t is the bequests obtained from the generation born at time t. Since production that begins at time t takes one period to generate output, a merchant born at time $t-1$ chooses capital bequest k_t, which is used in the manufacturing activity whose production begins at the same time t. At time $t+1$, a merchant born at time t and receiving capital bequests k_t will leave capital bequests k_{t+1} used in the manufacturing activity whose production begins at time t+1. In light of such preferences, the optimal consumption and offspring choices of a merchant are as follows (see Appendix A2):

$$\begin{aligned} c_{m,t+1} &= \delta_m \left(y_{m,t} - \bar{c}\right) \\ n_{m,t+1} &= \tfrac{(1-\delta_m)}{\bar{c}\theta}\left(y_{m,t} - \bar{c}\right)\end{aligned} \tag{4}$$

Note that $n_{m,t+1} > 0$ for $y_{m,t} > \bar{c}$. In the light of Eq. (4) each merchant's capital bequest is $k_{t+1} = n_{m,t+1}\tilde{k}_{t+1} = (1-\mu)k_t + \frac{(1-\delta_m)}{\bar{c}\theta}\left(y_{m,t} - \bar{c}\right)$, where μ is the constant depreciation rate of capital across generations.

3.2. Production in urban areas

Guilds dominated manufacturing production in urban areas, playing an essential role in the effective existence of market institutions. This aspect could be considered here, introducing a positive externality in the manufacturing production function in cities with no change in results; however, it is skipped to simplify the exposition. Merchants usually bore a cost to join guilds and gain access to the market and its services. In a comprehensive study of 1,102 guilds spanning European societies from 1233 to 1809, the mastership fee equated to more than a year's earnings for a worker. Additional charges for fraternity fees, masterpieces, examinations, and miscellaneous expenses were also significant (Epstein, 1998; Ogilvie, 2021, 2019, p. 125). In England and other promising areas for industrialization, guilds imposed rules and regulations on members (the entrepreneur/merchants) mainly in the form of constraints on allocating productive resources such as capital and employment.

We assume that the merchants pay a cost to join the guilds through a share $(1-\phi) \in (0,1)$ of the final manufacturing production in towns.[3] In particular, let $F_t = S\left(\eta_t K_t\right)^{\alpha}$ be the flow sunk cost merchants incur to join guilds and allow them to be operative and effective at each time $t \ge 0$, with $S > 0$, $\alpha \in (0,1)$ and $\alpha < 1-\gamma$. The variable η_t represents the aggregate share of each unit of capital employed in the cities. The value of the aggregate capital share in cities η_t – and how this value is obtained – will be clarified later.[4] In this way, the total membership of merchants to join guilds is as follows:

$$(1-\gamma)(1-\phi)\,Y_t^{MU} = F_t. \tag{5}$$

Let us suppose that guilds incur a constant cost of C regarding the final output (and capital) to effectively implement market institutions and related services. In this way, guilds optimally choose the capital share employed in towns, solving the following maximization problem:

$$\underset{(\eta_t K_t)}{Max} S\left(\eta_t K_t\right)^{\alpha} - C\left(\eta_t K_t\right),$$

that gives the optimal capital share employed in town $\eta_t \le \frac{1}{K_t}\left(\frac{\alpha S}{C}\right)^{\frac{1}{1-\alpha}}$, for any $K_t \ge 0$. At the beginning of the historical period under consideration $t = t_0$, this condition can be written as follows:

$$\eta_0 = \frac{1}{K_0}\left(\frac{\alpha S}{C}\right)^{\frac{1}{1-\alpha}}, \text{ for } K_0 > 0. \tag{6}$$

The aggregate manufacturing production function in the cities is

$$Y_t^{MU} = \left(\eta_t K_t\right)^{1-\gamma}\left(l_{u,t}\right)^{\gamma}, \tag{7}$$

where η_t represents the aggregate share of capital employed in the cities, and $l_{u,t}$ is the labor time of workers living in the urban areas. Substituting Eq. (7) into Eq. (5) we obtain the following:

$$(1-\gamma)(1-\phi)\left(\eta_t K_t\right)^{1-\gamma-\alpha}\left(l_{u,t}\right)^{\gamma} = S, \tag{8}$$

with $\alpha < 1-\gamma$.[5] From Eq. (8), the labor time employed in town can be obtained:

$$l_{u,t} = \left(\frac{S}{(1-\gamma)(1-\phi)}\right)^{\frac{1}{\gamma}}\left(\eta_t K_t\right)^{\frac{\gamma+\alpha-1}{\gamma}}. \tag{9}$$

Note that, given the manufacturing production as in Eq. (7), both guilds and merchants have the incentive to employ several workers in cities, which is as high as possible for any given level of aggregate capital $\eta_t K_t$. In this way, Eq. (9) holds as equality at each time $t \ge 0$. Considering the number of workers employed in towns as in Eq. (9), the aggregate manufacturing production in the towns can be reduced to the following:

$$Y_t^{MU} = \frac{S}{(1-\gamma)(1-\phi)}\left(\eta_t K_t\right)^{\alpha}, \tag{10}$$

which is increasing in capital employed in towns. From the above equation, the share of the final manufacturing production in cities

[3] In a bargaining framework, ϕ would be equivalent to the guilds' pay-off exponent in the Nash product expression (Mookherjee and Ray, 2002).

[4] We ask the reader to be patient here; no insight will be lost.

[5] Note that if $\alpha \ge 1-\gamma$, a profit maximization or a cost minimization behavior (or both) would generate a corner solution with no capital employed in the cities.

accruing to each merchant is obtained, i.e.,[6]

$$y_{m,t}^{MU} = \frac{1}{m_t}(1-\gamma)\phi Y_t^{MU} = \frac{1}{m_t}\frac{\phi S}{1-\phi}\left(\eta_t K_t\right)^{\alpha}. \tag{11}$$

Considering Eq. (7), the income flow paid to each worker living in cities – which is the marginal productivity of labor – is obtained:

$$y_{u,t} = \gamma\left(\frac{S}{(1-\gamma)(1-\phi)}\right)^{\frac{\gamma-1}{\gamma}}\left(\eta_t K_t\right)^{\left(\frac{\gamma-1}{\gamma}\right)(\alpha-1)}, \tag{12}$$

where Eq. (9) has been used and where aggregate capital is considered.

3.3. Production in rural areas

In rural areas, the economy displays two specific-factor technologies: farm production requires labor and land, whereas manufacturing production employs labor and capital. Two assumptions are introduced to simplify exposition without losing generality in the analysis. On the one hand, we do not consider the population working solely in the agricultural sector, such as those employed on large farmlands. Considering these workers would reinforce both the qualitative dynamics and results. On the other hand, we assume homogeneous land suitability for agricultural and livestock use, i.e., land has homogeneous suitability $G > 0$. Furthermore, in this case, the analysis and the qualitative results are reinforced by considering heterogeneous land suitability.[7] According to historical evidence, land is assumed to be free, so each individual living and working in the countryside faces neither land constraint nor land cost. We refer to lands outside the landlord's area and extensive farmland. What is not considered here is improvements in the technology level of agricultural activity, which could be accounted for in the model without affecting the main qualitative results and dynamics. Indeed, the agricultural technology levels between the more promising areas for development were very modest, to say the least (Vollrath, 2011).

A worker living in rural areas on a plot of land with suitability $G > 0$ can spend a share a_t of their labor time in agricultural activity and a share β_t of labor time in the manufacturing activity, with $\beta_t + a_t = D = 1$. The choice of the share of labor time endowment a worker decides to employ in agricultural and manufacturing activities is endogenous.

Production of agricultural good Y^A by a worker $j \in l_{r,t}$ living in rural areas at time t is described by the following technology frontier:

$$Y_{j,t}^A = (GL)^{1-\gamma}\left(1-\beta_t\right)^{\gamma}, \tag{13}$$

where G is the land suitability of the plot of land size L, which is assumed constant for each worker, and it is normalized to one for notational simplicity ($L = 1$) and $\left(1-\beta_t\right)$ is the individual's labor time devoted to agricultural activity and $\gamma \in (0,1)$.

The aggregate manufacturing production in the countryside (Y^{MC}) is obtained by combining capital with the labor time of workers living in rural areas according to the following technological frontier:

$$Y_t^{MC} = \left(\left(1-\eta_t\right)K_t\right)^{1-\gamma}\left(l_{r,t}\beta_t\right)^{\gamma}, \tag{14}$$

where $\left(1-\eta_t\right) \in (0,1)$ indicates the share of the aggregate capital K_t employed in the manufacturing sector in rural areas and $\left(l_{r,t}\beta_t\right)$ is the aggregate labor time devoted to manufacturing production in rural areas.[8]

Since capital is assumed to be a perfectly divisible good and each merchant behaves in the same way, the aggregate manufacturing production in the countryside as in Eq. (14) can be rewritten for each worker $j \in l_{r,t}$ as

$$Y_{jt}^{MC} = \left(\left(1-\eta_t\right)k_{jt}\right)^{1-\gamma}\left(\beta_t\right)^{\gamma}, \tag{15}$$

where Y_{jt}^{MC} is the production of manufactured goods by a worker, i.e., $Y_{jt}^{MC} = \frac{Y_t^{MC}}{l_{r,t}} = \frac{1}{l_{r,t}}\left(\left(1-\eta_t\right)K_t\right)^{1-\gamma}\left(l_{r,t}\beta_t\right)^{\gamma}$, and $\left(1-\eta_t\right)k_{jt} = \frac{(1-\eta_t)K_t}{l_{r,t}}$ is the capital used by the worker $j \in l_{r,t}$ at time $t \geq 0$.

3.4. Labor endowment allocation in rural areas

In this section, the optimal endogenous allocation of labor time between the agricultural and manufacturing production of a worker living in rural areas is obtained. From Eq. (15), the marginal productivity of the labor time in the manufacturing sector of a worker $j \in l_{r,t}$ living in rural areas is

$$\frac{\partial Y_{jt}^{MC}}{\partial \beta_t} = \gamma\left(\left(1-\eta_t\right)k_{jt}\right)^{1-\gamma}\left(\beta_t\right)^{\gamma-1}, \tag{16}$$

which is decreasing in the labor time β_t. Note that, for a given labor time allocation β_t, a higher capital share $\left(1-\eta_{jt}\right)$ and a higher aggregate capital K_t both shifts up the marginal productivity of the labor time in Eq. (16).

The marginal productivity of the labor time in the agricultural sector – as measured by an increase in the labor time spent in the agricultural activity $\left(1-\beta_t\right)$ in Eq. (13) – is

$$\frac{\partial Y_{jt}^A}{\partial\left(1-\beta_t\right)} = \gamma(G)^{1-\gamma}\left(1-\beta_t\right)^{\gamma-1}, \tag{17}$$

which is increasing in the labor time β_t. For a given labor time allocation $\left(1-\beta_t\right)$, higher land suitability G shifts up the marginal productivity of labor in Eq. (17), i.e., the higher the land suitability, the higher the marginal productivity of labor time in the agricultural sector. Each worker $j \in l_{r,t}$ allocates their labor time between agricultural and manufacturing activities so that a no-arbitrage condition between the marginal productivities in Eqs. (16) and (17) holds at each time $t \geq 0$ (see Appendix A1), i.e.,

$$\frac{\partial Y_{jt}^A}{\partial\left(1-\beta_t\right)} = \frac{\partial Y_{jt}^{MC}}{\partial \beta_t}. \tag{18}$$

Since $\frac{\partial Y_{jt}^A}{\partial(1-\beta_t)}$ is monotonic increasing in β_t. In contrast, $\frac{\partial Y_{jt}^{MC}}{\partial \beta_t}$ is monotonic decreasing in β_t, the no-arbitrage condition (18) allows an optimal share of labor time β_t^* – and then the labor effort both in agricultural and manufacturing sectors in the countryside – to be obtained:

$$\beta_t^* = \frac{\left(1-\eta_t\right)k_{jt}}{\left(1-\eta_t\right)k_{jt} + G}. \tag{19}$$

Since higher land suitability G shifts up the marginal productivity of labor time in the agricultural sector, the no-arbitrage condition (18) implies that, *ceteris paribus*, higher land suitability G generates a lower

[6] The inverse relationship between the income flow of each merchant in cities and the total number of merchants could also explain the historical evidence of why merchants had the incentive to limit guild membership.

[7] In particular, it can be assumed that land has heterogeneous suitability G_j over continuum support $\left[G_{\min}, G_{\max}\right]$, where $G_{\max}$ is the highest suitability index, and $G_{\min}$ is the lowest suitability index, with $G_{\max} > G_{\min} > 0$. Let G_{jt} indicate a land with suitability G_j occupied at time $t \geq 0$, with $G_{jt} \in \left[G_{\min}, G_{\max}\right]$. Since land is free and entails no cost, we could assume that individuals will occupy the more fertile lands first in this stylized economy. In particular, if at time $(t+1)$ a new land is occupied, it will have suitability $G_{j't+1} < G_{jt}$, with $G_{j't+1} \in \left[G_{\min}, G_{\max}\right]$. This assumption can also be read as decreasing productivity of a given plot of land when new labor is applied to the same plot of land.

[8] The same qualitative results hold considering different production functions for agriculture and manufacturing in rural areas. For the result to hold, land, labor, capital, and labor matter most in agricultural and manufacturing production, with appropriate parameter restrictions. The specific functional forms adopted here simplify calculations without losing generality in the analysis.

fraction of labor time spent in the manufacturing sector in rural areas, i.e., the higher G, the lower β_t^* is. Moreover, from Eq. (16), we derive that, *ceteris paribus*, the higher the capital share $\left(1-\eta_t\right)$ employed in the countryside, the more labor time β_t^* will be devoted to manufacturing activity in rural areas. The same holds for a higher aggregate capital K_t. In light of the above, a worker $j \in l_{r,t}$ living in the countryside earns an income flow y_{jt}^C at time $t \geq 0$ given by the sum of their agricultural production Y_{jt}^A and the manufacturing activity, i.e., $\frac{\partial Y_{jt}^{MC}}{\partial \beta_t}\beta_t^*$:

$$y_{r,t} = Y_{jt}^A + \frac{\partial Y_{jt}^{MC}}{\partial \beta_t}\beta_t^* = \frac{G+\gamma\left(1-\eta_t\right)k_{jt}}{\left(\left(1-\eta_t\right)k_{jt}+G\right)^{\gamma}}, \tag{20}$$

where the no-arbitrage condition for the allocation of the individual's labor time between agricultural and manufacturing activities, as in Eq. (19), has been considered.

3.5. Capital allocation between urban and rural areas

This section analyses how merchants allocate their capital between cities and rural areas. As stated in the historical background, the existence of guilds was essential to the effective existence of market institutions and related services, and for these reasons, merchants did not interrupt their membership with guilds. In particular, as long as merchants earned an income flow higher than alternative working activities, they had no economic incentive to break the rules on allocating resources imposed by guilds. In this way, merchants stick with the capital share employed in the cities η_0 until they earn a higher income than workers. Nevertheless, once this condition no longer held (i.e., $y_{m,t}^{MU} < y_{u,t}$), merchants were forced to break down the constraints on the allocation of capital imposed by guilds and chose to efficiently allocate their capital between cities and rural areas.

We now consider the merchant's individual choice regarding the allocation of capital between rural and urban areas when the constraints on the capital allocation imposed by guilds were broken down. From Eq. (7), the marginal productivity of the share of capital employed in towns η_t by a merchant is

$$\frac{\partial Y_t^{MU}}{\partial \eta_t} = \frac{S\phi}{\eta_t^{1-\alpha}(1-\phi)}K_t^{\alpha}, \tag{21}$$

where the number of workers employed in towns as in Eq. (9) is considered as given by each merchant. Eq. (21) is strictly decreasing and convex in the capital share η_t. Considering Eq. (14), the marginal productivity of the complementary share of one unit of capital employed in the manufacturing activity in rural areas is as follows:

$$\frac{\partial Y_t^{MC}}{\partial\left(1-\eta_t\right)} = K_t\frac{\left[\frac{(1-\gamma)(1-\eta_t)K_t}{l_{r,t}}+G\right]}{\left(\frac{(1-\eta_t)K_t}{l_{r,t}}+G\right)^{1+\gamma}}, \tag{22}$$

where the optimal labor share β_t^*, as in Eq. (19), is considered as given by each merchant. Eq. (22) is decreasing in the capital share $\left(1-\eta_t\right)$; it is then strictly increasing and convex in the capital share η_t. Note that, *ceteris paribus*, Eq. (22) shifts up with a higher level of aggregate capital and a lower level of land suitability G. Each merchant allocates each unit of capital in the manufacturing production between town and rural areas so that a no-arbitrage condition of the respective marginal productivities, as in Eqs. (21) and (22), holds at each time, i.e.,

$$\frac{\partial Y_t^{MU}}{\partial \eta_t} = \frac{\partial Y_t^{MC}}{\partial\left(1-\eta_t\right)}. \tag{23}$$

Since Eq. (21) is strictly monotonic decreasing and convex in the capital share η_t. In contrast, Eq. (22) is strictly monotonic increasing and convex in the capital share η_t, the optimal value η_t of capital share employed in town η_t and the optimal value of capital share employed in rural areas $\left(1-\eta_t\right)$ are obtained for each time t, given the number of workers living in rural areas.

Let us consider a given value η_t where marginal productivities are equalized. In any such intersection point, which is unique for any level of the aggregate capital K_t, the following is obtained:

$$K_t\frac{\left[\frac{(1-\gamma)(1-\eta_t)K_t}{l_{r,t}}+G\right]}{\left(\frac{(1-\eta_t)K_t}{l_{r,t}}+G\right)^{1+\gamma}} = \frac{S\phi}{\eta_t^{1-\alpha}(1-\phi)}K_t^{\alpha}, \tag{24}$$

which boils down to

$$\left.\frac{\frac{(1-\gamma)(1-\eta_t)K_t^{2-\alpha}}{l_{r,t}}+K_tG}{\left(\frac{(1-\eta_t)K_t}{l_{r,t}}+G\right)^{1+\gamma}} = \frac{S\phi}{\eta_t^{1-\alpha}(1-\phi)}\right|_{\eta_t=\eta_t^*}. \tag{25}$$

As long as merchants earned an income flow that was strictly higher than workers, they maintained the capital share employed in the cities η_0; thus, the no-arbitrage equation for the optimal allocation of capital as in Eq. (25) was not necessarily satisfied. However, once merchants were forced to break the constraints on the allocation of capital between cities and rural areas, they could choose the optimal share of capital employed both in cities and rural areas, η_t and $1-\eta_t$ respectively, according to the no-arbitrage condition (25).

3.6. Aggregate capital and manufacturing production

Utility maximization, subject to budget constraint of each merchant, generates the optimal choice for capital bequests $k_{t+1} = (1-\mu)k_t + \frac{(1-\delta_m)}{\bar{c}\theta}\left(y_{m,t}-\bar{c}\right)$ (see Appendix A2). Aggregating this last condition across merchants allows the law of motion of the aggregate capital to be obtained:

$$K_{t+1} = (1-\mu)K_t + \frac{\left(1-\delta_m\right)(1-\gamma)}{\bar{c}\theta}\left(Y_t^{MC}+\phi Y_t^{MU}-\bar{C}\right). \tag{26}$$

where $\bar{C}$ is the aggregate subsistence level. In this way, aggregate capital steadily increases over time – independent of the manufacturing production location – in either urban or rural areas. Considering manufacturing production in the countryside as in Eq. (14) and the aggregate manufacturing production in towns (10), the aggregate manufacturing production can be obtained, i.e.,

$$Y_t^M = \frac{\left(1-\eta_t\right)K_t}{\left(\left(1-\eta_t\right)k_{jt}+G\right)^{\gamma}} + \frac{S}{(1-\gamma)(1-\phi)}\left(\eta_t K_t\right)^{\alpha}, \tag{27}$$

where the optimal labor time allocation between agricultural and manufacturing activities as in Eq. (19) has been considered.

4. Simulation and calibration

This section examines our model's fundamental relations by simulating the pre-industrial economy's behavior under different conditions. The initial assumptions of our empirical exercise are as follows. Initially, the manufacturing activity is mainly located in urban areas, as it was until the late Middle Ages, implying that the share of capital employed in cities (η) in the first period is arbitrarily large. The large value of η reflects the initial power of guilds, which can restrain capital mobility. In the countryside, peasants spend almost all their labor time in agriculture, and only a tiny fraction is devoted to manufacturing (β) because agriculture was still a labor-intensive activity during the pre-industrial period, as discussed in Section 2.5. We calibrate the suitability of land[9] (G=0.7). Furthermore, we assume that labor input, without any distinction, is three times larger in the countryside in pre-industrial European economies than in the city (Allen, 2000).

[9] The value of 0.7 is obtained by normalizing the highest index of land suitability observed to 1 and picking the corresponding value of land suitability for the North of England.

Table 1
Calibration: parameters and initial values.

γ	labor share	0.65	Voigtländer and Voth, 2006
δ_m	fraction of income consumed by merchants	0.8	our calibration
δ_l	fraction of income consumed by workers	0.75	”
$(1-\phi)$	cost to join the guilds per unit of output	0.2	”
α	productivity parameter	0.1	”
$\bar{c}$	level of subsistence	0.3	”
θ	share of subsistence for rising child	0.5	”
μ	capital depreciation rate	0.05	”
K	capital stock	2	”
β	time spent in manufacturing in the countryside	0.1	”
η	fraction of capital used in cities	0.75	”
μ	depreciation rate	0.05	”
m	n. of merchants	1	normalized

A critical characteristic of the model is the dynamic law of change of capital stock. Once production in the city and the countryside is known at time t, we can get capital stock at time $t+1$. The reproduction rates of labor inputs and the new capital stock allow us to endogenously estimate the fundamental variables of our model at time $t+2$: η and β. Estimates of incomes, reproduction rates of the labor force, and manufacturing production in both the city and countryside at time $t+2$ follow, and the new stock of capital available at time $t+3$ is obtained. We recursively estimate the pattern of the pre-industrial economy for 15 generations lasting 20 years each, ideally covering the pre-industrial economy from the mid-15th century to the mid-18th century, at the time of the widespread introduction of the steam engine in England, the first industrialized country (Nuvolari et al., 2011).

From a historical point of view, the power of guilds lasted for several centuries before losing control of urban manufacturing. Guilds acted in several ways, and one of the most significant constraints was to restrain the export of capital outside urban areas, binding merchants to produce in towns. We insert this fact into our simulation by keeping the fraction of capital employed in cities constant at its initial value $\eta = 0.75$.

Relevant technological changes in agriculture happened only in the late 18th century, as explained in Section 2.5. Indeed, agriculture was labor-intensive at the beginning of the 15th century; thus, we assume the peasants devoted much of their labor time to agriculture, which is reflected in the initial level of $\beta = 0.1$.

Fig. 8 plots the patterns of output per capita (Panel A), the capital per worker (Panel B), the fraction of time spent in manufacturing in the countryside, and the fraction of capital used in cities (Panel C), and the incomes earned by workers (in the city and the countryside) and by merchants (Panel D).

In the scenario of Fig. 8, we detect a moderate transition to manufacturing in the countryside where the fraction of time peasants spend on producing manufacturing goods shifts from 0.1 to 0.55. In this scenario, capital per worker increases and peaks for some generations but eventually decreases. Both findings are consistent with the hypothesis that guilds could retain their power, impeding the outflow of capital from the city to the countryside, thus preventing capital accumulation and the diffusion of free manufacturing activity outside cities. As the 17th century unfolded, the power of guilds reduced across Europe, particularly in England (see Section 2.3). Our model suggests the mechanism that prompted English merchants to evade the guilds' restrictions. In Panel D in Fig. 8, after eight generations, the income earned by urban workers surpasses the income earned by merchants; thus, we identify the point at which merchants were incentivized to break the guild fetters where those earned by urban workers outpace their income. Merchants decide to move production out of urban areas if their income falls below the income of their full-time employees. In this case, merchants would prefer to turn themselves into workers and shut down the business. Consequently, we leave the capital share η_t free to vary around 1600. When merchants escaped the guilds' constraints on capital allocation, they could allocate their capital according to the marginal productivities described by the no-arbitrage condition of Eq. (23).

Fig. 9 describes the behavior of such an economy; we identify with England, the country with the weakest guild system. From panel A, we observe that the output per capita and the capital per worker are higher in the unlocked economy. What drives the model is the efficient allocation of capital by merchants, which accelerates the peasants' decision to spend more time in manufacturing and prompts the shift of capital outside the city. The initial significant value of η drops because merchants can allocate capital. In the countryside, capital accumulates faster than in the city, making the transition to a deeper diffusion of manufacturing possible, as shown by the behavior of the labor time spent in manufacturing in rural areas, i.e., β_t. Eventually, manufacturing production moves from the city to the countryside without technological change, externalities, or economies of scale offered by urban centers.

Note that in both scenarios with strong and weak guilds, as in Figs. 8 and 9 respectively, the Malthusian mechanism was at work until about the middle of the 15th century. Indeed, given merchants' low initial level of individual income, their fertility rate was negative. This situation determined an increase in income followed by a higher fertility rate that reduced the income again, generating the Malthusian trap until the middle of the 15th century.[10]

As merchants evaded the restrictions of guilds and moved capital to the countryside, a sharp initial increase in the average individual income of merchants is observed, capturing the first merchants' income in efficiently allocating their capital between the city and the countryside (Panel D). Then, over time, more and more merchants, whose number increases due to a higher fertility rate (see Section 5, Fig. 12), exploited the most efficient way to allocate capital, which absorbed the initial increase in the average individual income of merchants.

5. Historical comparative analysis

Following Stokey (2001), the calibrated model with the relaxation of guild constraints is compared with the existing data for England. Unfortunately, we do not have the complete set of series that we would use for the pre-industrial English economy. One available is the GDP per capita at a constant price, elaborated by Broadberry et al. (2015). Panel A in Fig. 10 plots our estimates of GDP per capita at some benchmark years against England's annual GDP per capita. Data have been converted to index numbers. The two series reveal that the patterns are similar. The prediction of our model can capture the initial stagnation from the mid-15th century to the early 17th century and the moderate growth from 1620 onward. Instead, Panel B shows the pattern of labor time peasants spend in manufacturing (β) against an analogous proxy from historical data. Such a measure, though imperfect and primarily raw, is the ratio between people engaged in nonagricultural

[10] In our set-up, the Malthusian trap was mainly at work for merchants, not for the workers in the city that had a comparable income in the first period, because of the merchants' preferences for capital bequests.

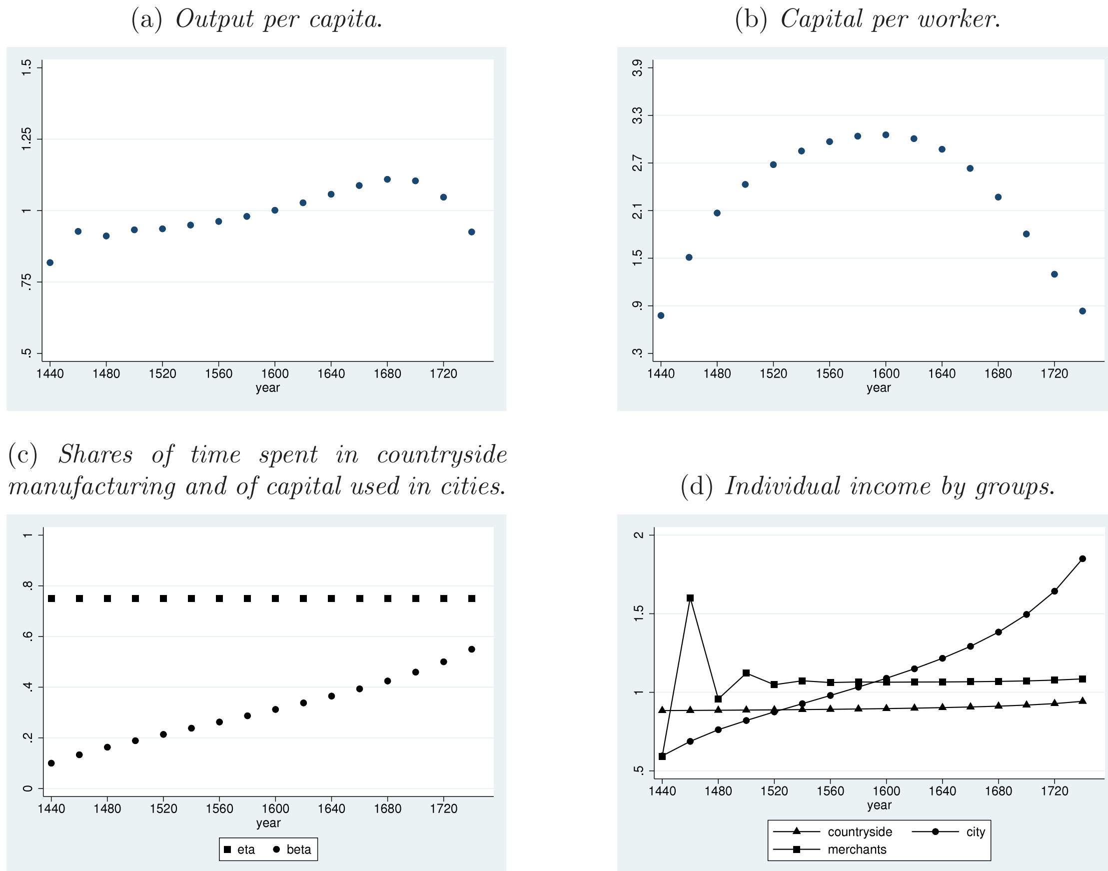


Fig. 8. Model's prediction with full Guilds power.

activity living in the countryside and the population of the countryside engaged in agricultural tasks (Allen, 2000) pp.8–9).

Finally, we computed the average income earned by urban and rural workers of our economy, excluding merchants, to be compared with an analogous measure of historical English incomes. The income earned in the English economy has been calculated as the average income of agricultural and rural workers provided by Clark (2005, 2006). Panel C shows this comparison, highlighting that our average laborers' income converges with the historical figures.

Our model accounts for the following stylized facts that had characterized rural pre-industrial England from the middle of the 15th century: (1) diffusion of rural manufacturing through the shift of labor time from agriculture to manufacturing, (2) moderate capital deepening, and (3) moderate but persistent rise of output per capita.

We provide the employed labor force dynamics and the net fertility rate. Because we have an overlapping generation model set-up, the total population at each time t is given by the young generation of individuals, which is the employment at time t in our model, and by the old generation of individuals, which is the employment at the time $(t-1)$. We compare the English historical employment data at a given time with the employment of the young generation of the same period. Panel A of Fig. 11 shows that the employment pattern is consistent with comparable English historical figures. Moreover, we compare the simulated net fertility rate with the historical net fertility rate taken by Wilson and Woods (1991). Panel B of Fig. 11 shows that our simulation fits the historical data of the net fertility rate since the middle of the 17th century when guilds were weakening.

The following section exploits the exogenous variations of land suitability for the comparative analysis across Europe. Since England is an intermediate case, we show our model's predictions for countries with land suitability that were either lower or higher than England.

5.1. Little divergence across europe

We next examine whether our model and simulation help to understand why England had comparative advantages over the rest of Europe to embark on industrialization. To this end, we use a simple comparative statics exercise. We study how the pattern of the main variables changes in response to variations of land suitability, considering the European economies that are widely recognized to have had the chance to embark on industrialization since the 15th century (Allen, 2003). First, we explore the model's behavior in a scenario with land suitability lower than our baseline setting. If the suitability of land is too low to deliver enough food resources, peasants will spend more time in manufacturing to supplement their income so that manufacturing production will be higher, given the share of capital in the countryside constant at its initial value $(1-\eta) = 0.25$. Nevertheless, the low land suitability induces peasants to accept a lower wage flow in manufacturing activity, which implies a low-income flow earned by workers in rural areas. While peasants will choose to shift more and more of their labor time from agricultural to manufacturing, merchants pay a lower wage to workers employed in rural manufacturing production. Capital accumulates over time in cities and the countryside, and merchants earn higher incomes than workers' wages over the centuries. In this way, merchants have no incentive to break down the rules imposed by guilds on allocating capital between rural areas and cities, and the economy is trapped with a lower per capita income than in the baseline scenario. The behavior of the main variables is represented in Fig. 12.

Therefore, land suitability lower than the benchmark used in the previous simulations stabilizes the model in a complete guild power condition, voiding the incentives for merchants to break the guilds'

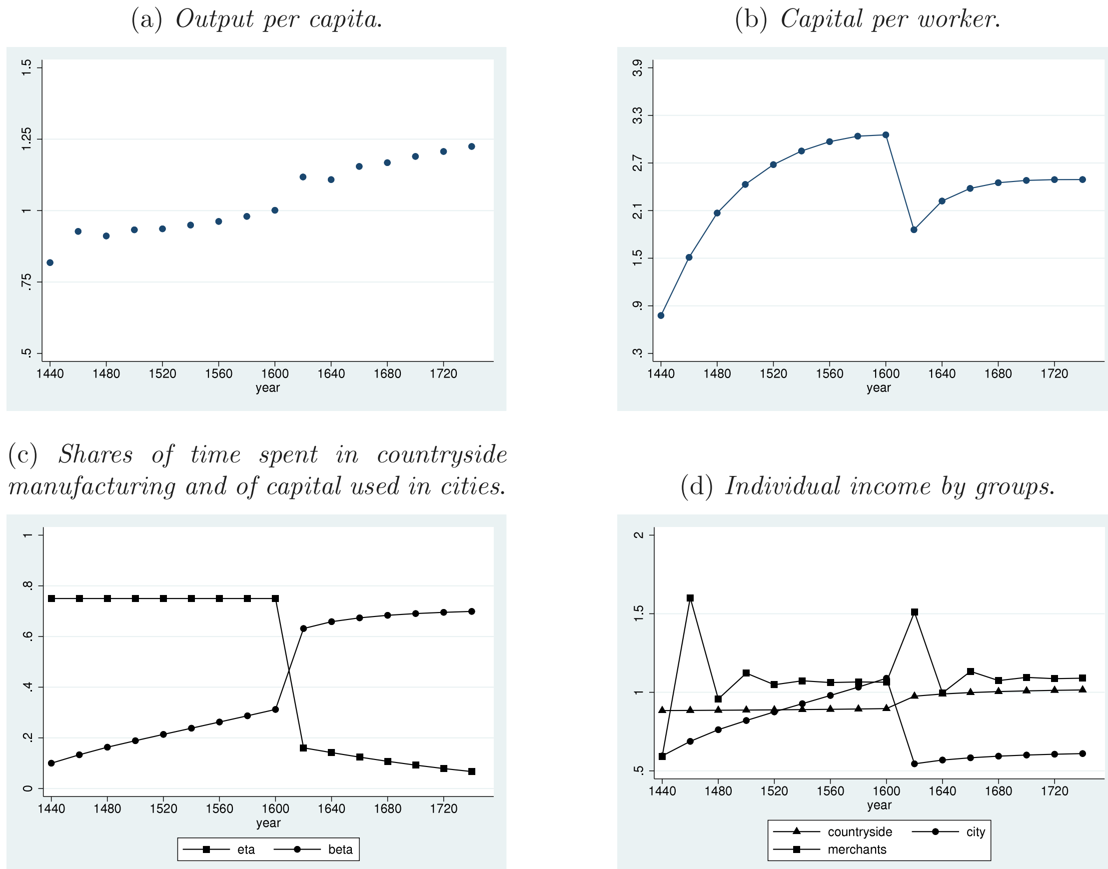


Fig. 9. Model's prediction with lower Guild power.

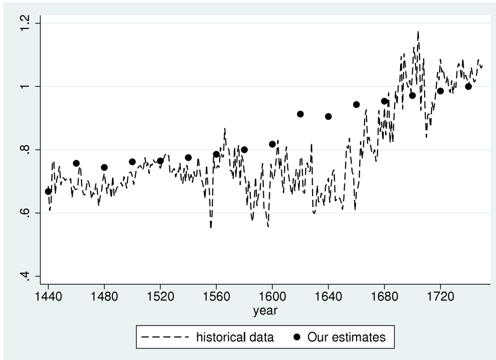
system. As a result, income per capita is lower than in the baseline scenario, though peasants devote substantial labor time to manufacturing, and capital per worker is increased.

The economy in Fig. 12 refers to areas in continental Europe where land suitability was lower than in England. Italy and Spain occupy a lower position in the rank of natural land suitability presented in Fig. 4. Italy was the forerunner of the European economy until the early 17th century when its long-term decline was initiated as a response to a decline in urban manufacturing and struggling agriculture (Cipolla, 1952). Spain was a frontrunner in exploiting the Atlantic trade routes and draining precious metals to vitalize its economy. Its income per capita peaked around 1570 and then declined, never reaching the same level until the late 19th century, probably because Spain failed to trigger an agricultural revolution (de la Escosura et al., 2022). Both countries had strong guilds, which survived until the late 19th century, and the diffusion of manufacturing outside cities emerged as a response to the rural population's struggles in supporting their subsistence.

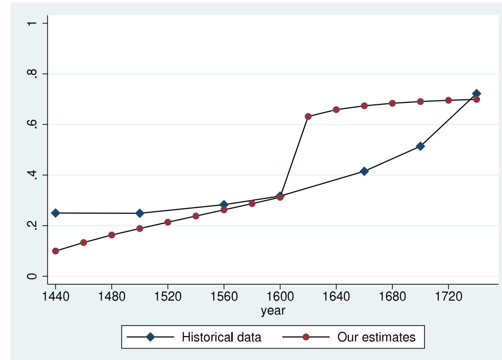
To contextualize the model's predictions in the broader economic history literature, we discuss the apparent mismatch between a rising share of labor time peasants spend in manufacturing and a low level of land suitability. Recent estimates of occupational share for Italy, a laggard country, compiled by Chilosi and Ciccarelli (2022) calculated that in the first half of the 19th century, Northern Italy had 27 of people living in the countryside not working in agriculture, and only 6% in the Southern part of the country. With a comparatively low level of land suitability and relatively high power of Guilds, the model predicts an increasing share of labor time spent in rural manufacturing activity, i.e., a higher β, which may appear in contrast with the evidence above. At its initial stage, our model's β level closely approximates the nonagricultural employment figures for rural areas in Italy that have been reported in prior research. Specifically, Herlihy and Klapisch-Zuber (1978, chap. 10) estimate that approximately 6% of rural families were engaged in nonagricultural activities within the countryside. Based on these estimates and Chilosi and Ciccarelli's (2022) data for the north of Italy, the implied growth rate of nonagricultural workers in the countryside between 1400 and 1800 would exceed 350%, suggesting a marked acceleration in the diffusion of protoindustry. Furthermore, the qualitative evidence regarding the expansion of rural industry presents a mixed picture. On the one hand, Sella (1997) argues that manufacturing in the countryside offset the decline of urban industrial activities during the 17th century. On the other hand, Malanima (2011) expresses ambivalence on this topic, highlighting the diffusion of the silk industry in rural areas while remaining noncommittal on whether this trend represents a broader expansion of the rural industry. Above all, it is worth noting that in our model, the result is also influenced by the guilds' strength with the land suitability. The predictions of Fig. 12 suggest a higher level and a faster increase of time spent in manufacturing in the countryside, yet they substantially convey a similar message: an expansion of protoindustry. However, this result should be read in tandem with the pattern of the share of capital employed in the countryside, i.e., $(1-\eta)$, which suggests that nonagricultural rural workers had a lower level of disposable capital and thus lower labor productivity, which ultimately trapped Italy in the underdevelopment since the second half of the 17th century.

In contrast, in the context of a higher level of land suitability, as in the Low Countries, guilds lost their power, but peasants had less scope for shifting their labor time to manufacturing because of the higher income earned in the agricultural activity. Our model predicts a break of the guilds' fetters that was mostly contemporaneous to England (Ogilvie, 2014) and a value of β that was roughly half of the English case. As Federico (2016, p. 127) pointed out, England diverged markedly from some areas of the Low Countries that maintained a

(a) *Output per capita (Index 1740=1).*



(b) *time spent by peasant in manufacturing.*



(c) *Average income of workers (Index 1740=100).*

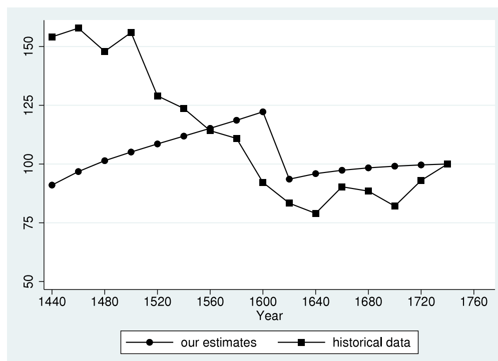
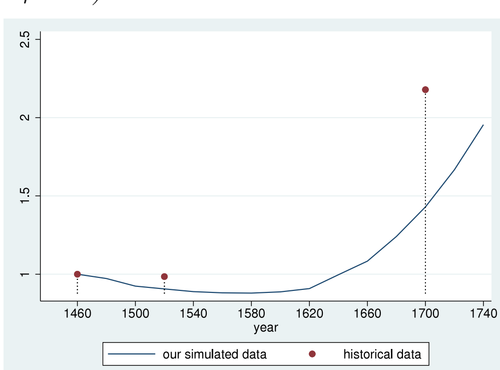


Fig. 10. Model's prediction and English historical data.
Source: Historical output per capita is from Broadberry et al. (2015). The fraction of time spent in rural manufacturing is defined in Section 2.2 and comes from Allen (2000). For average income, see text.

(a) *Total occupation in England (Index 1460=1).*



(b) *Index of English net fertility rate.*

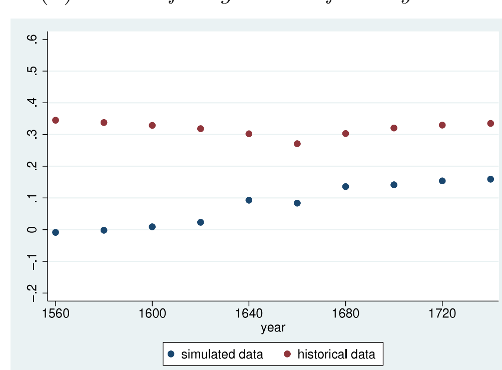


Fig. 11. Demographic pattern.
Source: Historical occupation is obtained by applying values of Table 7 panel b and Table 8 panel B from Broadberry et al. (2015) to the total of 1700 laborers force drawn by Broadberry et al. (2015) Table 3 (Line 7). The index of net fertility rates is from Wilson and Woods (1991), Table 1, Index I_f.

significant proportion of their rural population engaged in agriculture throughout the pre-industrial era. In such a scenario, income per capita was 90% lower than in England. Historical data for the Low Countries (Belgium plus the Netherlands) elaborated by the Maddison project (Bolt and Van Zanden, 2020) inform us that the English GDP per capita was in 1750 already 5% higher than the Low Countries and that the Low Countries had been stagnating since 1650. Those data are almost in line with what we get from our simulation.[11]

[11] We reconstructed the GDP per capita of the Low Countries by summing up the GDP of Belgium and Netherlands and then deflating for the sum of their respective population. Let us note that the Netherlands GDP refers to

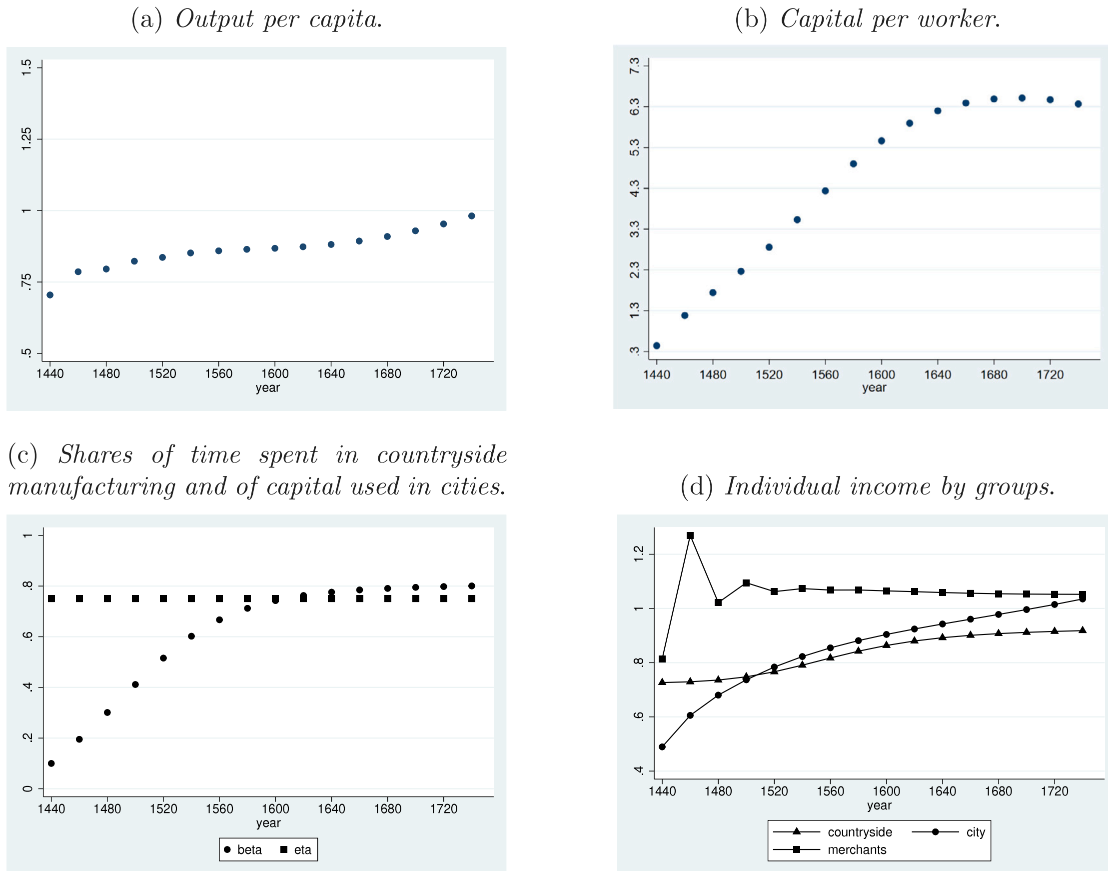


Fig. 12. Model's prediction with full guild power and low land suitability.

6. Conclusions

The fundamental causes determining the sustained economic growth of the Western European economy from the 18th century have attracted the attention of both growth economists and economic historians. We showed how England achieved higher income per capita by 1750, a condition recognized to have increased the probability of starting the Industrial Revolution.

We present a model of manufacturing diffusion outside the urban areas that have been historically present in Europe since the 15th century. The shift of labor time from agriculture to manufacturing in rural areas, together with a decline in the guilds' strength in addressing the entrepreneurs' choices on capital allocation between city and countryside, provided England with an advantage in terms of higher income per capita by 1750 compared to the other promising areas for industrialization across Europe.

This process was gradual and took at least two centuries. Indeed, since the 15th century, peasants began to scale up manufacturing, yet the shift of manufacturing production outside cities was limited and constrained by the guilds. Although guilds imposed constraints on entrepreneurs to allocate capital efficiently, they relied on the guild system to benefit from participation in the market institutions and related facilities. In England, this inefficient equilibrium lasted as long as the cost of joining the guild system remained lower than the benefits earned by merchants. Once the entrepreneurs-merchants lost a significant part of their rents from participation in this inefficient equilibrium, they triggered the diffusion of manufacturing in the countryside by efficiently allocating capital between cities and rural areas.

From the perspective of comparative development of Europe, the relative productivity of agricultural to manufacturing activities in rural areas, together with the relative strength of guilds, played an essential role in shaping the behavior of pre-industrial economies. In particular, we show that land suitability ultimately correlates to incentives for breaking the guild constraints. In areas where land suitability was lower than in England (in its northern portion), such as pre-industrial Italy or Spain, merchants could hire labor time for manufacturing in rural areas at a low wage and sustain their income. As long as this condition held, merchants had no incentive to escape the guilds' control, and the economy remained trapped in a stagnating pattern. In contrast, higher land suitability and a relatively weak guild system, as in the Low Countries, allowed the peasants to call for a high wage for their labor time in manufacturing, reducing the incentives of merchants to move capital in the countryside. In some areas of France, such as Normandy, high land suitability combined with a strong guild and privileges systems delivered an economy of low income and capital accumulation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Holland, the country's most prosperous area. It is likely that if we had the GDP per capita for the Netherlands as a whole, the level of per capita GDP would have been lower, and our results would be even stronger. This difference was enough to give England a small, though crucial, advantage to trigger the Industrial Revolution.

Economic growth before the Industrial Revolution: Rural product ion and guilds in the European Little Divergence (Original data) (Mendeley Data)

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.econmod.2023.106590.

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