Spatial Competition, Innovation and Institutions: The Industrial Revolution and the Great Divergence*

Klaus Desmet
SMU and CEPR

Avner Greif
Stanford University

Stephen L. Parente
University of Illinois at Urbana-Champaign

September 2015

Abstract

The period leading up to the *Industrial Revolution* saw a dramatic increase in spatial competition in England. This paper advances a theory in which the intensity of inter-city competition determines both the incentives of firms to adopt labor-saving technologies and the incentives of specialized workers to resist them. After calibrating the model to England in 1600, it uses data on city sizes and inter-city distances between 1600 and 1850 and shows that the model predicts guilds giving up at the beginning of the nineteenth century. In a similar exercise for China, where inter-city competition was much weaker, the model predicts guilds blocking technology until the early twentieth century. The theory can therefore account for both the *Industrial Revolution* and the *Great Divergence*.

1 Introduction

In the centuries leading up to the *Industrial Revolution* England experienced a dramatic increase in spatial competition. Between 1600 and 1800, the average distance of a city in England to its closest neighbor dropped from more than 60 km to less than 20 km. Over the same time period, the average city's access to population in other cities located in a 20 km radius increased from less than 1,000 to more than 70,000. This paper advances the idea that this often overlooked fact of increasing inter-city competition might be key to understanding why England was the first nation to industrialize. In particular, it develops a theory where the degree of spatial competition affects both the incentives of firms to introduce more productive technology and the incentives of specialized factors of production to block this technology.

We illustrate our theory in a simple spatial model consisting of two cities or regions, each with a continuum of monopolistically competitive industrial sectors and a perfectly competitive

*Desmet: Department of Economics, Southern Methodist University. E-mail: kdesmet@smu.edu; Greif: Department of Economics, Stanford University. E-mail: avner@stanford.edu.; Parente: Department of Economics, University of Illinois. E-mail: parente@illinois.edu.

agricultural hinterland. There are two technologies for producing an industrial good: an artisanal technology and a modern technology. The modern technology has two important advantages relative to the artisanal one. First, it does not need skilled workers to operate, and second, output per production worker is greater. Initially, all industrial firms use the artisanal technology. Each can then switch to the modern technology but there is a fixed cost to doing so. Additionally, they must have the resources to overcome the potential resistance by skilled workers in their industry and city, who faced with the prospect of reduced earnings, have the ability to form a special interest group for the purpose of blocking the modern technology. At the risk of slightly abusing terminology, we refer to such a special interest group as a craft guild.[1]

We use this structure to examine how the degree of spatial competition affects the equilibrium outcomes, focusing primarily on the time when craft guilds form to block the introduction of the modern technology and the time when they give up their resistance. The critical feature of our abstraction for understanding this timing is a preference construct in which the price elasticity of demand for each industrial good increases with the size of the market. More specifically, we assume Hotelling-Lancaster preferences so that for each industrial good, each household has an ideal variety that corresponds to his location on the unit circle. The boundedness of the variety space implies that as cities become larger or inter-city transport costs drop, the competition between neighboring varieties on the unit circle increases. As a result, the price elasticity of demand increases, markups drop and firms have to become larger to break even (Helpman and Krugman, 1985; Hummels and Lugovskyy, 2009). Greater inter-city competition, therefore, makes it more attractive for a firm to switch to the modern technology, because its larger size allows it to spread the fixed cost of innovation over a greater quantity of output. This will be easier if an industry in a given city can steal business from the same industry in the other city, so that once again the degree of inter-city competition will be decisive.

The model predicts three stages in an economy's development as the degree of spatial competition intensifies. Starting off in a situation where inter-city competition is weak, either because neighboring cities are small, transport costs are large, or distances between cities are great, no firm can bear the fixed innovation cost, making the modern technology unprofitable. In this case the equilibrium is characterized by all firms in all industries and cities using the artisanal

[1] As we will discuss later, the role of craft guilds was not limited to dictating production processes.

technology and no technology-blocking guilds anywhere. As inter-city competition strengthens, a point is reached where an individual firm in a given city and industry has an incentive to switch to the modern technology. However, the profits from operating the modern technology are too small to overcome workers' resistance, either by compensating them directly for reduced earnings or by defeating them through the judicial or political system. In this case, the equilibrium is characterized by all firms using the artisanal technology but guilds existing in all industries and cities. It is only when inter-city competition becomes sufficiently strong that profits from innovation are large enough to defeat guild resistance. At that point guilds disband, resistance to technology adoption ceases, firms innovate and the economy takes off.

A key result of the model is that market size *per se* is not sufficient for guilds to disband. Rather, what matters is the interplay of city size and inter-city transport costs. To be more precise, in the absence of inter-city trade, an industry in a given city that introduces the modern technology is unable to steal business from the other city, and will never have large enough profits to overcome guild resistance regardless of how large its own city is. As an illustration, compare an economy with one city of size x to another economy with two cities, each of size $x/2$. In the presence of inter-city transport costs, effective market size is larger in the first economy than in the second, yet the theory predicts innovation can only occur in the second economy. Critical for this result is the assumption that technology-blocking institutions are organized at the city-industry level. As such, the effective monopoly power of a craft guild is greater in the first economy than in the second. In our theory inter-city competition is thus at the basis of resistance to innovation breaking down and the economy taking off.

We assess the plausibility of our theory in a number of ways. First, we provide a historical account of the relation between guilds, spatial competition and innovation. We start by showing that the amount of spatial competition was an important factor in determining the intensity of resistance by guilds. We then provide empirical evidence suggesting that locations in England that were subject to stronger inter-city competition had a greater incentive to innovate at the beginning of the *Industrial Revolution*. Second, we undertake a calibration exercise to examine if the theory is quantitatively consistent with England's development. More specifically, we use data on city sizes and inter-city distances between 1400 and 1600 to calibrate the model to the date when it became common for English guilds to block the introduction of labor-saving technologies. We then use the calibrated model to determine the date at which resistance should have ended and the English economy should have taken off using data on city sizes and distances between cities from 1600 to 1850. We find that the model predicts well the timing of the *Industrial Revolution*.

To further assess the plausibility of our theory, we apply it to the *Great Divergence* between China and Northwestern Europe. Until the eighteenth century, China was on par with Europe, but then their development paths started to diverge dramatically. To examine if differences in spatial competition could explain the *Great Divergence*, we examine the predictions of our calibrated model for resistance to labor-saving technology in China. To that purpose, we use Chinese data on city sizes and distances between cities between 1700 and 1900. Importantly, we show that the model predicts that technology-blocking guilds in China should have survived until the start of the twentieth century, thus generating the *Great Divergence* between the West and the East. To complete the application to China's development, we also provide historical evidence that shows how the emergence of European-style professional guilds in China coincided with the introduction of new labor-saving technologies from the West.

The model's ability to predict the lag in China's development is important for two reasons. First, the *Great Divergence* is arguably one of the major puzzles in economic history and so clearly a question of interest in itself. Second, the comparison between England and China sheds light on the relative importance of city size and inter-city distance. In the pre-industrial period, China was on every account larger than England, not just in terms of its total population, but also in terms of its urban population. These are not the dimensions that matter most in our theory, however. Far more important is the distance between cities, and here China was at a major disadvantage. Using Chinese data on average city size and distance between cities, we find that the calibrated model accounts for the continuation of guild resistance in China until the end of the nineteenth century.

The literature that seeks to understand why the *Industrial Revolution* first happened in Northwestern Europe is extensive. Diverse explanations favoring Northwestern Europe abound, some of which are: close proximity to a cheap energy source (Pomeranz, 2000), greater patience and stronger preferences for education (Galor and Moav 2002; Clark 2007), and institutions that better protected property rights (North, 1981; Mokyr, 1990).[2] Some of this literature, which includes Voigtländer and Voth (2006), Shiue and Keller (2007) and Desmet and Parente (2012), offers an explanation based on market size. In these papers, however, there is no suggestion that

[2] For a comprehensive list, see McCloskey (2007).

the degree of spatial competition and the geographic distribution of economic activity are critical. An increase in population or a decrease in trade costs have the same impact in these papers. That is not the case in our theory: an increase in market size in the absence of trade is never enough for resistance to end and take-off to occur.

This paper is related to at least two other strands in the literature. One strand is the literature on the importance of competition for innovation. Empirical evidence in favor of the positive effect of competition includes Nickell (1996), Galdón-Sánchez and Schmitz (2002) and Aghion et al. (2005). There are also a large number of theoretical papers that describe mechanisms whereby stronger competition leads to more innovation. Of particular note is the paper by Desmet and Parente (2010), which uses the Hotelling-Lancaster construct to show how an increase in market size leads to stronger competition between varieties. Although we borrow their basic setup, there are some key differences, the most important one being the endogenous formation of guilds that can block the introduction of more productive technology.

Another strand is the literature on technology-blocking institutions. The importance of resistance to the introduction of more productive technology by special interests in the context of the *Industrial Revolution* is a prominent theme in the work of Morison (1966) and Mokyr (1990). Important theoretical papers in this area include Krusell and Rios-Rull (1996), Parente and Prescott (1999) and Dinopoulos and Syropoulos (2007). The two most closely related papers are Holmes and Schmitz (1995) and Desmet and Parente (2014). In Holmes and Schmitz (1995), although trade is likewise shown to eliminate resistance, there is no role for market size and the theory remains silent on how an economy escapes an equilibrium where both regions block innovation. In Desmet and Parente (2014) workers form guilds or unions to block the introduction of a better production process until they can be bought off. However, that paper takes market size to be city size, thus ignoring spatial competition and geography.

The rest of the paper is organized as follows. Section 2 provides historical and empirical evidence from England on the relation between spatial competition, guild resistance and innovation. Section 3 presents the model and analyzes the theoretical interaction between the spatial distribution of cities, the incentives for firms to innovate, and the incentives for guilds to resist. Section 4 applies the theory to the *Industrial Revolution*. Section 5 applies the theory to the *Great Divergence*. Section 6 concludes.

2 Spatial Competition, Guilds and Innovation in England

In this section we start by documenting the increase in spatial competition in England between 1400 and 1900. We then provide a history of the guilds, and show how spatial competition affected both the intensity of innovation and the resistance by guilds to the introduction of labor-saving technologies.

2.1 The Evolution of Spatial Competition

A key point of this paper is that the increase in spatial competition was instrumental to England's industrial development. In this subsection we document the change in inter-city competition from the Early Modern period to the *Industrial Revolution* in England.

2.1.1 Data

To construct measures of inter-city competition over time, we use historical data on city populations in England from Bairoch et al. (1988). The data set has information on all cities that reached a population of at least 5,000 at some point between 800 and 1850. We use data for 1400, 1600, 1700, 1750, 1800 and 1850. Before turning to the construction of different measures of the degree of spatial competition, Panel A in Table 1 reports the average city size over time. As can be seen, city size was fairly stable between 1600 and 1800, hovering around 20,000, but then started to increase dramatically, more than doubling by 1850.

2.1.2 Measures of Spatial Competition

When measuring the degree of spatial competition, we aim to capture the ease by which firms can steal customers from close-by cities. As we will see, this is the type of measure our theory will be interested in. As there is no single accepted measure of spatial competition, we construct three different indices.

We start with some notation. Let $\mathcal{R}$ denote the set of cities in a country with $r \in \mathcal{R}$ denoting a particular city, and let $\delta^{rr'}$denote the distance between cities r and r'. A first simple measure of the spatial competition faced by city r is the total population of other cities located within a circle of radius δ around it. We denote this measure by S_1^r, which is defined as

$$S_1^r = \sum_{r' \in \mathcal{R}, r' \neq r, \delta^{rr'} < \delta} L^{r'}. \tag{1}$$

Table 1: Spatial Competition in England

Year	1400	1600	1700	1750	1800	1850
A. Average City Size (thousands)						
	11.2	19.1	25.1	28.0	21.2	50.8
B. Population access $\leq$ 20 km (S_1, thousands)						
	0.0	0.0	1.3	5.2	73.8	190.6
C. Population access, spatial decay $\gamma = 1.5$ (S_2, thousands)						
	0.0	0.2	0.6	0.8	4.1	11.6
D. Distance to reach same number of consumers (S_3, km)						
	93	70	44	44	21	21

As the ease of stealing customers from neighboring cities will be important in our theory, we exclude the city's own population in (1). In light of the era we study, we set δ to 20 km based on the idea that one day's travel typically did not exceed 40 km roundtrip. As can be seen in Panel B of Table 1, between 1700 and 1800 there was a dramatic increase in population access, from around 1,000 to 74,000. This increase continued in the nineteenth century, with population access reaching 191,000 in 1850.

A second measure of the spatial competition faced by city r, referred to as S_2^r, takes a distance-weighted approach to market access:

$$S_2^r = \sum_{r' \in \mathcal{R}, r' \neq r} L^r (\delta^{rr'})^{-\gamma}, \tag{2}$$

where $\gamma \geq 0$. That is, a city's market access is the weighted sum of the populations of all other cities, with the weights declining with distance. The value of parameter γ is key: the higher its value, the faster the spatial decay. There are only a few historical studies using (2). Based on data of many countries, Jacks, Meissner and Novy (2011) find a value of 1.2 for the time period 1870-1913. Given the dearth of historical evidence, an alternative strategy is to use present-day evidence from developing countries as a proxy. In a meta-analysis, Disdier and Head (2008) suggest a mean value of 0.9 for the elasticity of trade to distance. Studies that focus exclusively on developing countries give higher values. For example, Daumal and Zignago (2010) estimate an elasticity of 1.9 for Brazil. Taken together, these studies suggest a value for γ between 1.2 and 1.9, so we take 1.5 as our benchmark. Panel C reports the estimates of S_2^r with $\gamma = 1.5$. Although the increase is less stark with this measure of spatial competition, there is still a seven-fold increase during the eighteenth century.

Lastly, we compute the average distance for a city to reach the same number of consumers as in the own city. As we will see, this is the measure that will most closely fits our theory. As such, it will be useful for our calibration exercise. For each city r, define a vector of which the elements L_i^r represent the populations of the other cities, ordered by their distance to r. That is, L_1^r is the population of the closest city to r, L_2^r is the population of the second closest city to r, and so on. Likewise, for each city r, define a second vector of which the elements δ_j^r represent the distances to the other cities, again ordered from the closest city to the most far away city. We can define

$$
\begin{aligned}
S_3^r \quad = \quad & \sum_{i=1}^{\bar{\iota}} \delta_i^r L_i^r / \sum_{i=1}^{\bar{\iota}} L_i^r \\
& \text{where } \bar{\iota} = \text{argmin} \sum_{i=1}^{\bar{\iota}} L_i^r \\
& \text{s.t. } \sum_{i=1}^{\bar{\iota}} L_i^r \geq L^r \\
& \quad L_{\bar{\iota}}^r = L^r - \sum_{i=1}^{\bar{\iota}-1} L_i^r
\end{aligned} \tag{3}
$$

As shown in Panel D, the average distance to reach the same number of consumers in England was 44 km in 1700. This distance dropped by more than half, to 21 km, by 1800. Taken together, these different measures show how the degree of spatial competition increased dramatically in England between 1600 and 1850.

2.2 The Rise and Decline of Guilds and their Attitude towards Innovation

In this subsection we describe the history of guilds in England, focusing on their rise, their decline and their attitude towards innovation. We aim to make the point that craft guilds, though originally not created as organizations bent on resisting innovation, over time turned against the introduction of more productive technologies, especially if they were labor-saving.

Rise and decline of guilds. Guilds emerged in Europe in the Medieval period and survived in one form or another until the Early Modern period. A guild (gild, Hansa, company, livery, or mystery) was a corporation, that is, a self-governed organization established to pursue the common interest of its members. The emergence of the guilds is best understood in the context of the institutional vacuum that prevailed from the ninth to the eleventh century in Europe. Faced with states that were unable to provide local public goods in a satisfactory manner, European society responded by creating different types of corporations such as guilds, communes, city-states, monasteries and military orders (Greif, 2006). The emergence of the guilds was also a manifestation of the broader social and political process through which European society became increasingly organized around local or professional interests, rather than around state or kinship interests.

There were two main types of guilds in Europe: the merchant guilds, which had rights over some form of exchange (e.g., retail, wholesale, export, etc.), and the craft guilds, which had regulatory rights over some craft (e.g., tanning, dying, wool, cloth, etc.). Merchant guilds started losing power as early as the fourteenth century, and were largely irrelevant by the end of the fifteenth century (Seligman, 1887), well before the advent of the many labor-saving technologies that fueled the *Industrial Revolution*. In contrast, craft guilds became more numerous in the fourteenth century as local authorities increasingly delegated regulatory powers to them. Craft guilds were more common in large cities than in small towns, and membership was widespread (De Munck, Lourens and Lucassen, 2006; Desmet and Parente, 2014). For example, perhaps as many as three quarters of the male population in London in the mid-sixteenth century were guild members (Gadd and Wallis, 2002). Their influence and presence made guilds an important part of the European urban landscape until the early nineteenth century (Gadd and Wallis, 2002; Britnell, 2008).

Officially, guilds were made illegal in England with the *Municipal Corporations Act of 1835*, which stated that "every person in any borough may keep any shop for the sale of all lawful wares and merchandises by wholesale or retail, and use every lawful trade, occupation…".[3] This was the culmination of a decline that had started in the mid-to-late eighteenth century, with many guilds disappearing out of their own accord (Epstein, 2008; Gadd and Wallis, 2002). In that sense, the decline of the guilds should be viewed as an endogenous, rather than an exogenous, event. It is unlikely that the government would have been able to abolish the guilds in 1835 had they not already been severely weakened in the preceding decades.

Attitude towards innovation. Although initially craft guilds were private, benevolent societies providing a social safety net with poor relief and old-age benefits to widows, by the seventeenth century they were in a process of transformation. According to Hibbert (1891, p. 103), "The old Gilds, which had lived through the shocks of the reformation, and the Elizabethan changes,

[3]Gross (1890), p. 165.

had quite altered their character. The new ones which had arisen differed widely from the old fraternities. Instead of being brotherhoods of craftsmen desirous of advancing the public weal, they were now mere societies of capitalists, intent only on private and personal advantage... There is a constant endeavor to restrict the companies to favored individuals. Every 'foreigner' is subjected to a heavy fine, which grows larger in amount as the companies feel the trade slipping from their hands in spite of their desperate endeavors to restrict it."

It is this later incarnation of guilds that shaped the view of Adam Smith (1774) who considered them to be rent-seeking organizations that limited entry through an excessively lengthy seven-year apprenticeship system. This same negative perception is echoed by Pirenne (1936, p. 185-186) who argued that the main aim of the craft guilds was to "protect the artisan, not just from external competition, but also from the competition of his fellow-members". Hence, even if in the earlier stages guilds might have spurred some innovation, "most authorities are in agreement that eventually much of the guild system was overtaken by technologically reactionary forces which instead of protecting innovators threatened them" (Mokyr, 1997, p. 31).

This is not to say that the apprenticeship system, as enshrined in the Statute of Artificers of 1563, did not have its virtues. Craft guilds, through the apprenticeship system, played an important role in the training and transmission of human capital, which was key to upholding the quality of locally produced goods (Epstein, 1998). Although initially this had a positive effect on productivity, over time it became a break on progress, and it led to a situation of technological status quo. By imposing procedures that stipulated exactly how something had to be produced, the apprenticeship system became conservative: it ensured the quality of a product, given the existing technology, but it was rigid in that it curtailed experimentation and innovation (Mokyr, 1998). The barriers to entry imposed on craftsmen who were trained elsewhere further contributed to this inertia by limiting the spatial diffusion of knowledge.

Of course there was not a complete absence of innovation. In fact, there was some craft-based innovation, and guilds did not oppose all types of technological advances. For example, craft-based innovation aimed at saving capital or enhancing skills was not frowned upon (Epstein, 1998). However, it was a different matter with labor-saving technologies. Attempts to block the adoption of labor-saving technologies became quite frequent in the seventeenth, and especially the eighteenth, century. In England, these attempts culminated in the Luddite riots of 1811 to 1816.

The increase in resistance in the early stages of the *Industrial Revolution* is consistent with the patent records that show a rise in the fraction of discoveries that were labor-saving in nature. MacLeod (1998, p. 160) summarizes the beliefs of British patentees between 1662 and 1800 regarding the impact their invention would have. Of the 505 patent applications from 1662 to 1750 where impacts were given by patentees, 45% claimed the invention would be labor-augmenting, 37% claimed it would be capital-saving, and 1% believed it would increase government revenue (11%). More importantly, only 2% declared the invention would save labor. For the period 1750 to 1800, at the beginning of the *Industrial Revolution*, this number increased fourfold. Many of these patents were at the heart of worker resistance.

Although there is some disagreement over the general attitude of guilds towards technology,[4] the above discussion suggests that there is a broad consensus on a number of points. First, although craft guilds were initially not created as anti-competitive organizations set on resisting technological change, they increasingly took on that role in the later stages of their existence. Second, although there was a certain amount of craft-based innovation that occurred within the guild structure, it was not of the labor-saving type. When in the seventeenth and eighteenth centuries industries were faced with the possibility of adopting new labor-saving technologies, it is therefore not surprising that craft guilds, fearing that the employment of skilled artisans was at stake, resisted.

2.3 Spatial Competition and Innovation

How did the intensity of spatial competition factor into this history? This question will be fundamental to the theory put forth in this paper. In this subsection, we provide evidence that the degree of spatial competition was an important factor in determining the incentives and ability of the craft guilds to resist labor-saving technology.

In England transport infrastructure improved during the eighteenth century through the introduction of toll roads and canals (Szostak, 1991). Effective distances between cities shrank and labor mobility became increasingly hard to restrict. It is within this setting that guilds in England began to lose their power and disappear. The coincidence in the timing of the weakening of guilds with increased spatial competition does, of course, not prove that the latter caused the former. There are case studies, however, that do suggest this causal channel. An example from the Netherlands shows the importance of inter-city competition for resistance: in 1604 the city

[4]The positivists claim that guilds fostered the diffusion of knowledge (Hickson and Thompson, 1991; Epstein, 1998, 2008; Richardson, 2004), whereas the negativists argue that guilds blocked technological progress (Ogilvie, 2008).

government of Leiden refused to support the craft guilds' pleas to ban a newly invented ribbon loom because it worried the industry would move to the nearby city of Delft ('t Hart, 1993; Mokyr, 1998). In the same vein, Ogilvie (2004) gives the example of Lille, a town in Northern France, where the textile industry relaxed guild regulations in the late seventeenth century because of greater competition from rural weavers.

If one location did not adopt a new technology, often the neighboring location would. If guilds could have controlled multiple cities, things might have turned out differently. But craft guilds were local, and their authority did typically not extend beyond the own city. In England, their monopoly power was further reduced by the growth of free towns, such as Birmingham and Manchester, which became attractive locations for industrialization. "Most of the new industries did not come under the Apprenticeship Act [Statute of Artificers], and were consequently free and unshackled. Such formidable rivals drew away trade from the old privileged boroughs. The companies were quite unable to retain their monopolies" (Hibbert 1891, p. 129). In tracing the shearers' attempt to block the introduction of the gig mill in the West of England, Randall (1991) argues that the end of resistance coincides with its use in other parts of England.

The importance of spatial competition for effective resistance is also apparent in several episodes where the inter-city competition was international in nature. Randall (1991) shows that resistance to the scribbling machine in the West of England textile industry ended in 1795 following a trade boom.[5] Binfield (2004) argues that the most famous example of worker resistance, the Luddite riots between 1811 and 1817, was a response to changes in trade openness. The mill workers associated with the Luddites were only anti-technology after the British government cut off trade with France via the *Prince Regent's Order in Council of 1811* in response to the Napoleonic War. Following the removal of this order in 1817, this resistance and violence ended.[6]

The examples above suggest that resistance to new technologies broke down in part because of the high degree of spatial competition between cities. To provide more formal empirical evidence of the link between the spatial structure of the economy and innovation, we examine whether English counties that were subject to greater inter-city competition were also more likely to adopt new technologies at the beginning of the *Industrial Revolution*. To measure the degree of spatial

[5] In a different time and a different place, this is similar to what happened to the US iron ore industry in the 1980s, when it experienced productivity gains in the face of increased international competition from Brazil (Schmitz, 2005).

[6] Wage concessions, abatement in food prices and military force were also contributing factors to ending the Luddite resistance according to Binfield (2004).

competition, we use S_1^r, i.e., the population within a radius of 20 km of city r. As an alternative measure, we also compute the number of cities in a radius of 20 km. We then take the county-level population-weighted average of these two measures. For counties with no cities, we set our spatial competition measures to zero. Alternatively, we could drop those counties. In our analysis, we use both approaches.

To measure innovation, we rely on British county-level patent data between 1796 and 1820 from the Royal Society of Arts (1784-1845). In particular, we use the number of patents per capita in a county as a proxy for that county's propensity to adopt new technologies. If inventions can happen anywhere in the county, it would be reasonable to measure this patent-intensity as the number of patents divided by the total population of the county. If, instead, inventions only occur in cities, then we would want to divide the number of patents by the county's urban population. In our analysis we experiment with both measures. One potential issue is that our patent data give the location of the invention, rather than the location of the adoption. As already discussed, there are many instances of technologies being developed in one place and being adopted in another. This is not a problem if both locations are in the same county. If they are not in the same county, then for our analysis to be meaningful, it must be that there is a positive correlation between the patent intensity of a location and its propensity to adopt new technologies.

Table 2: Correlation Patents per Capita with Different Measures of Spatial Competition

	Patents per total population		Patents per urban population	
	(1)	(2)	(3)	(4)
	All counties	Urban counties	All counties	Urban counties
Market access < 20 km	0..3127**	0.2938*	0.8781***	0.8757***
Number of cities < 20 km	0.6600***	0.6453***	0.3847**	0.3635**

* Statistically significant at 10%, ** at 5% and *** at 1%

Table 2 reports the correlations between patent intensity and different measures of spatial competition. The positive correlations imply that innovation is stronger in counties where cities are subject to greater spatial competition. Columns (1) and (2) use the number of patents in a county divided by the total population of the county as its measure of innovation. Column (1) uses all counties, whereas Column (2) only focuses on counties that have a positive urban population. Consistent with the theory, the correlations are always positive, and in all cases the correlations are statistically significant at the 1%, 5% or 10% level. Columns (3) and (4) report the same correlations, but now we measure innovation as the number of patents in a county divided by the urban population of the county. The correlations continue to be positive, and their statistical significance is stronger, between 1% and 5%. This allows us to conclude that during the *Industrial Revolution* spatial competition was positively associated with innovation intensity.

In addition to increasing inter-city competition, there were other factors that contributed to the weakening of guild resistance. One of these is the expansion of poor relief. Although the poor laws were originally motivated by civic humanism (Slack, 1999), by the late eighteenth century contemporaries recognized that they had a role to play in maintaining social order in the face of the introduction of new labor-saving technology. Sir F. M. Eden, a prominent social scientist of the time, noted in his 1797 seminal book on poverty that “machines or contrivances calculated to lessen labour ... throw many industrious individuals out of work; and thus create distresses that are sometimes exceedingly calamitous. Still, however, as the only point of view, in which a nation can regard such schemes of a reform, is to consider how far they actually do or do not promote the general wealth, by raising the largest quantity of provisions, or materials for manufacture, at the least cost, their inconvenience to individuals will be soften and mitigated, indeed, as far as it is practical” (Eden, 1797, vol. 1, p. xiv). This more comprehensive approach to poor relief was particularly pronounced in the newly industrialized areas in the North and West (King, 2000). At the same time the system became more predictable and better financed than before (Solar, 1995). Paid for by local taxes, the newly-generated wealth from industrialization allowed for a continued increase in social spending.

2.4 Summary

There are at least four stylized facts that come out of the empirical and historical evidence presented in the preceding subsections. First, there was an important increase in the degree of spatial competition in the time period leading up to the *Industrial Revolution*. Second, the attempt of guilds to block the adoption of labor-saving technologies roughly coincided with that same time period. Third, the guilds’ success in resisting innovation was limited by the degree of spatial competition. Fourth, compensating the losers from industrialization contributed to maintaining social order, thus facilitating England’s take-off.

3 The Model

In this section we present a simple model that is consistent with the stylized facts we just discussed. In particular, it captures how resistance to process innovation depends on an economy's spatial organization. The basic setup of the model is inspired by that of Desmet and Parente (2010), with two important differences. First, we allow for the existence of city-industry guilds that can dictate technology use in their city and industry. The interaction between those guilds and the spatial organization of the economy will determine the incentives and the possibility to innovate. Second, we allow for a continuum of industries, rather than for just one industry. This implies that any given guild has power over a specific industry in a city, rather than over a city's entire economy.

We proceed in three steps. First, we describe the model economy and characterize the equilibrium conditions when the only technology available is the artisanal one. Second, we introduce a modern technology that does not require the skilled labor input that is needed in the artisanal technology, and we characterize the equilibrium conditions for which guilds exist and block the use of the modern technology. Third, we show analytically that if trade is prohibitively costly between cities, guilds never disband and the artisanal technology is used forever. A corollary is that inter-city trade is necessary for the modern technology to be adopted.

3.1 Artisanal Technology

The model consists of two identical city-regions, referred to as the East (E) and the West (W) and indexed by the superscript $r \in \{W, E\}$. Each city-region is populated by a continuum of measure L of one-period lived households, of which measure $(1-\mu)L$ are skilled and measure μL are unskilled. We denote a household's type by the superscript $h \in \{u, s\}$, where u refers to unskilled and s to skilled. Households of each type and each city-region are uniformly distributed around the unit circle. Each household inelastically supplies one unit of labor to the region in which it resides. There is no household migration between city-regions.

3.1.1 Preferences and Utility Maximization

Preferences. Household preferences are defined over an agricultural good and a continuum of industrial goods. We use the letter $i \in [0,1]$ to denote a particular industrial good, the letter v_i to denote a particular variety of that good i, and the letter V_i to denote the set of varieties of good i produced in the economy, where V_i^r refers to the set of varieties of good i produced in city-region r.

Goods can be thought of as textiles, furniture, wines, etc., whereas varieties correspond to different colors, flavors or textures of these goods.

Preferences over each industrial good is of the Hotelling-Lancaster type, meaning that a household's location on the unit circle identifies the particular variety of each good that it prefers over all others. Let $d_{v_i\tilde{v}}$ denote the shortest arc distance between variety v_i and the household's ideal variety $\tilde{v}$ for a given good i.[7] The utility that a household residing in r and located at point $\tilde{v}$ on the unit circle derives from consuming c_a units of the agricultural good and c_{v_i} units of variety v of good i is given by

$$(1-\alpha)\log c_a^{rh} + \alpha \int_0^1 \log g(c_{v_i}^{rh} | v_i \in V_i) di, \tag{4}$$

where, following Hummels and Lugovskyy (2009),

$$g(c_{v_i}^{rh} | v_i \in V_i) = \max_{v_i \in V_i} \left(\frac{c_{v_i}^{rh}}{1 + d_{v_i\tilde{v}}^{\beta}} \right). \tag{5}$$

In expression (5), the denominator $1 + d_{v_i\tilde{v}}^{\beta}$, where $\beta > 0$, is the quantity of variety v_i that gives the household the same utility as one unit of its ideal variety $\tilde{v}$.

Utility maximization. The utility function (5) implies that a household residing in city-region r buys the variety $\hat{v}_i^r$ that minimizes the cost of the quantity equivalent to one unit of its ideal variety, $\tilde{v}$:

$$\hat{v}_i^r = \text{argmin}[p_{v_i}^r (1 + d_{v_i\tilde{v}}^{\beta}) | v_i \in V_i], \tag{6}$$

where $p_{v_i}^r$ is the price of variety v_i in city-region r. Let y^{rh} be the income of a household of type h residing in city-region r. The household's budget constraint is then

$$p_a^r c_a^{rh} + \int_0^1 \left(\sum_{v_i \in V_i} p_{v_i}^r c_{v_i}^{rh} \right) di \leq y^{rh}. \tag{7}$$

Maximizing (4) subject to (7) implies that a household of type h residing in r with ideal variety $\tilde{v}$ consumes

$$p_a^r c_a^{rh} = (1-\alpha) y^{rh} \tag{8}$$

and

$$p_{\hat{v}_i^r}^r c_{\hat{v}_i^r}^{rh} = \alpha y^{rh}. \tag{9}$$

[7]Since a household's ideal variety depends on its location on the unit circle, $\tilde{v}$ does not require a subscript i.

3.1.2 Technologies and Profit Maximization

Farms. The farm sector produces a homogeneous, non-tradable good according to a linear technology that uses unskilled labor only. Let Q_a^r denote farm output in city-region r. Then

$$Q_a^r = \Gamma_a L_a^r, \tag{10}$$

where Γ_a is farm-sector TFP and L_a^r is farm-sector employment in city-region r. In the absence of TFP differences across the city-regions, we normalize the agricultural price to 1 in both regions,

$$p_a = 1. \tag{11}$$

Profit maximization then implies a common agricultural wage rate across regions given by

$$w_a = \Gamma_a. \tag{12}$$

Industries. The industrial sector consists of a continuum of industries of measure one. Each industry produces a set of differentiated varieties. The market structure is monopolistically competitive. Trade in varieties across cities-regions is subject to iceberg transport costs: to deliver one unit of a variety produced in one city-region to the other city-region, $\tau > 1$ units must be shipped.

Each firm uses an increasing return artisanal production technology.[8] The artisanal technology can only use skilled workers. The output of a firm in city-region r that produces variety v_i is

$$Q_{v_i}^r = \Gamma_v [L_{v_i}^r - \kappa], \tag{13}$$

where κ is the fixed operating costs in units of labor and Γ_v is the marginal productivity.

Because of the fixed operating cost, each variety is produced by a single firm that therefore acts as a monopolist. When maximizing profits, each monopolist takes the choices of other firms as given. For reasons of space, we only present the profit maximization problem facing Eastern firms. Expressions for Western firms can be derived by analogy. To distinguish between the production and the consumption locations, we use a double superscript, where the first superscript refers to the production location and the second refers to the consumption location.

Using the production function (13), together with the fact that the Eastern firm's production meets consumption of Eastern and Western consumers, namely,

$$Q_{v_i}^E = C_{v_i}^{EE} + \tau C_{v_i}^{EW}, \tag{14}$$

[8] We use the adjective "artisanal" because we will later introduce a "modern" technology.

we can write an Eastern firm's profits, $\Pi^E_{v_i}$ as

$$\Pi^E_{v_i} = p^{EE}_{v_i} C^{EE}_{v_i} + p^{EW}_{v_i} C^{EW}_{v_i} - w^E_x [\kappa + \frac{C^{EE}_{v_i} + \tau C^{EW}_{v_i}}{\Gamma_v}], \tag{15}$$

where $p^{EE}_{v_i}$, $p^{EW}_{v_i}$, $C^{EE}_{v_i}$ and $C^{EW}_{v_i}$ are the prices and consumption levels of an Eastern-produced variety in the Eastern and the Western markets, and w^E_x is the Eastern wage rate in the industrial sector.

An Eastern firm producing variety v_i chooses the price in the East, $p^{EE}_{v_i}$, and the price in the West, $p^{EW}_{v_i}$ to maximize (15), subject to demand in the East and demand in the West, taking the wage rate in the industrial sector, w^E_x, as given. The profit-maximizing price in each market is a markup over the marginal unit cost, so that

$$p^{EE}_{v_i} = \frac{w^E_x}{\Gamma_v} \frac{\varepsilon^{EE}_{v_i}}{\varepsilon^{EE}_{v_i} - 1} \tag{16}$$

and

$$\frac{p^{EW}_{v_i}}{\tau} = \frac{w^E_x}{\Gamma_v} \frac{\varepsilon^{EW}_{v_i}}{\varepsilon^{EW}_{v_i} - 1}, \tag{17}$$

where $\varepsilon^{EE}_{v_i}$ and $\varepsilon^{EW}_{v_i}$are the price elasticities of demand for variety v_i in the East and the West. Namely,

$$\varepsilon^{EE}_{v_i} = -\frac{\partial C^{EE}_{v_i}}{\partial p^{EE}_{v_i}} \frac{p^{EE}_{v_i}}{C^{EE}_{v_i}}$$

and

$$\varepsilon^{EW}_{v_i} = -\frac{\partial C^{EW}_{v_i}}{\partial p^{EW}_{v_i}} \frac{p^{EW}_{v_i}}{C^{EW}_{v_i}}.$$

3.1.3 Aggregate Demands

The analysis focuses on the properties of the model's symmetric Nash equilibria. In such an equilibrium, all industrial firms charge the same price. In addition, firms are equally spaced around the unit circle, with each variety of one city-region having two varieties of the other city-region as its closest neighbors. Before defining the symmetric Nash equilibrium, it is instructive to derive the aggregate demands for each differentiated industrial good as well as the aggregate demand for the agricultural good.

Agricultural good. Assuming symmetry, there is no reason to trade the agricultural good across city-regions. Since each household spends a fraction $1 - \alpha$ of its income on the agricultural good, the aggregate demand in city-region r is simply

$$C_a^r = (1-\alpha)((1-\mu)w_x^r + \mu w_a^r)L. \tag{18}$$

Differentiated industrial goods. Because all varieties are equally spaced around the unit circle, aggregate demand for an Eastern firm producing variety v^E depends only on the locations and the prices of its closest neighbors to its right and its left on the unit circle, which are both Western firms. Since these two Western-produced neighboring varieties are each located at the same distance d from the Eastern-produced variety in a symmetric equilibrium, we do not need to differentiate between them, and therefore denote each by v^W. The Eastern household who is indifferent between buying varieties v^E and v^W is the one located at distance d^{EE} from v^E, where d^{EE} satisfies

$$p^{WE}[1 + (d - d^{EE})^\beta] = p^{EE}[1 + (d^{EE})^\beta]. \tag{19}$$

Given this indifference condition applies to households both to the right and to the left of v^E, a share $2d^{EE}$ of Eastern households consumes variety v^E. As both skilled and unskilled Eastern households are uniformly distributed along the unit circle and each household spends a share α of its wage earnings on a single variety in any given industry, the East's demand for v^E is

$$C^{EE} = \frac{2d^{EE}\alpha[(1-\mu)w_x^E + \mu w_a^E]L}{p^{EE}}. \tag{20}$$

By analogy we can derive the West's demand for v^E,

$$C^{EW} = \frac{2d^{EW}\alpha[(1-\mu)w_x^W + \mu w_a^W]L}{p^{EW}}, \tag{21}$$

where d^{EW} gives the distance from v^E at which a Western household is indifferent between consuming v^E or v^W, so that

$$p^{WW}[1 + (d - d^{EW})^\beta] = p^{EW}[1 + (d^{EW})^\beta]. \tag{22}$$

Price elasticity. The East's demand (20) implies that

$$-\frac{\partial C^{EE}}{\partial p^{EE}}\frac{p^{EE}}{C^{EE}} = 1 - \frac{\partial d^{EE}}{\partial p^{EE}}\frac{p^{EE}}{d^{EE}}. \tag{23}$$

After solving for the partial derivative $\partial d^{EE}/\partial p^{EE}$ by taking the total derivative of the indifference equation (19) with respect to p^{EE}, we get

$$\varepsilon^{EE} = 1 + \frac{[1 + (d^{EE})^\beta]p^{EE}}{[p^{EE}\beta(d^{EE})^{\beta-1} + p^{WE}\beta(d - d^{EE})^{\beta-1}]d^{EE}}. \tag{24}$$

By analogy, the elasticity faced by an Eastern firm in the West is

$$\varepsilon^{EW} = 1 + \frac{[1+(d^{EW})^{\beta}]p^{EW}}{[p^{EW}\beta(d^{EW})^{\beta-1} + p^{WW}\beta(d-d^{EW})^{\beta-1})d^{EW}}. \tag{25}$$

3.1.4 Equilibrium Conditions

Goods and labor market clearing. In addition to utility maximization and profit maximization, the market for each industrial variety clears in equilibrium, as expressed in (14). The corresponding condition for the agricultural market is

$$\Gamma_a L_a^r = C_a^r. \tag{26}$$

The labor markets must also clear in each country. As d is the shortest-arc distance between any two varieties on the unit circle, it follows that the number of varieties of each industrial good produced in the economy is $1/d$. Because there is measure one of industrial goods, symmetry implies that each city-region produces $1/(2d)$ varieties of each industrial good. Given the production function (13), each Eastern firm employs $\kappa + \frac{C^{EE}+\tau C^{EW}}{\Gamma}$ units of skilled labor. The labor market clearing conditions are then:

$$\begin{aligned}(1-\mu)L &= \frac{1}{2d}[\kappa + \frac{C^{EE}+\tau C^{EW}}{\Gamma_v}] \\ L_a^E &= \mu L.\end{aligned} \tag{27}$$

Zero profit condition. Because of free entry and exit, all firms make zero profits. For Eastern firms in any given industry, i, this condition is

$$p^{EE}C^{EE} + p^{EW}C^{EW} - w_x^E[\kappa + \frac{C^{EE} \ \ + \tau C^{EW}}{\Gamma}] = 0. \tag{28}$$

The zero profit condition in each industry determines the number of varieties produced in the East. We are now ready to define a symmetric equilibrium.

Definition of Symmetric Artisanal Equilibrium. *An Artisanal Technology Symmetric Equilibrium (ARTSE) is a vector of elements (p^{ii*}, ε^{ii*},p^{ij*}, ε^{ij*}, w_x^{i*}, w_a^{i*} ,d^*, d^{ii*}, d^{ij*}, Q^{i*}, Q_a^{i*}, C^{ii*}, C^{ij*}, C_a^{i*},V^{i*}), where $i,j \in \{E,W\}$, $i \neq j$, and $x^{ii*} = x^{jj*}$, $x^{ij*} = x^{ji*}$ and $x^{i*} = x^{j*}$ for any variable x^*, that satisfies conditions (10), (12), (14), (16), (17), (19), (20), (21), (22), (18), (24), (25), (26),(27), and (28), as well as the corresponding conditions for Western industrial firms.*

3.2 Innovation, Guilds and Spatial Competition

We now study the formation of worker groups that block the adoption of a modern technology and their subsequent disappearance. Starting off in a symmetric equilibrium where all firms use the artisanal technology, a modern technology becomes available. Compared to the artisanal technology, the modern technology has the advantage of a higher marginal productivity, but the drawback of a higher fixed cost. In addition, the modern technology can indistinctly use skilled and unskilled workers. As a result, the skilled may lose because of low-wage competition from the unskilled if a firm decides to switch to the modern technology.

In this section we analyze whether it is profitable for an individual firm in a given city-region to adopt the modern technology. We then discuss whether the skilled workers of the industry and city-region of the adopting firm have an incentive to form a guild to prevent the switch to the modern technology. Finally, we establish conditions for an industry in a city-region to buy out guild members so they stop blocking adoption. Our main interest is to analyze the relation between the size of the market, the degree of spatial competition, and the existence of technology-blocking institutions.

3.2.1 Incentive to Adopt Modern Technology

We start by defining the modern technology. The output of a firm in city-region r that produces variety v_i using the modern technology is

$$Q^r_{v_i} = \Gamma^r_v(1+\gamma)[L^r_{v_i} - \kappa - \phi], \tag{29}$$

where $\phi > 0$ is the fixed operating costs in units of labor, and $\gamma > 0$ and $\Gamma^r_v(1+\gamma)$ is the marginal productivity.

We now establish the condition for a firm to adopt the modern technology, assuming all other firms are still using the artisanal technology. Denote by $\Pi^{E\prime}$ the profit of a single firm deviating from the artisanal technology. The deviation condition for a firm to switch to the modern technology can then be written as

$$\Pi^{E\prime} > 0, \qquad \text{where}$$

$$\begin{aligned} &\Pi^{E\prime} = \max_{p^{EE\prime}, p^{EW\prime}} \{p^{EE\prime}C^{EE\prime} + p^{EW\prime}C^{EW\prime} - w_a[\kappa + \phi + \frac{C^{EE\prime} + \tau C^{EW\prime}}{\Gamma_v(1+\gamma)}]\} \\ \text{s.t.} \quad &C^{EE\prime} = \frac{2d^{EE\prime}\alpha[(1-\mu)w_x^E + \mu w_a^E]L}{p^{EE\prime}} \\ &C^{EW\prime} = \frac{2d^{EW\prime}\alpha[(1-\mu)w_x^W + \mu w_a^W]L}{p^{EW\prime}}. \end{aligned} \tag{30}$$

The "prime" superscripts refer to variables specific to a firm deviating from an equilibrium where all other firms use the artisanal technology. Because a firm can hire any workers when it uses the modern technology, the wage rate is w_a. We assume parameters are such that $w_a < w_x^r$.

Computing the deviating profits $\Pi^{E\prime}$ requires re-writing (19) and (22), the two conditions that determine the Eastern household and the Western household that are indifferent between the deviating firm's variety and its neighbors' varieties to the left and to the right,

$$p^{WE}[1 + (d - d^{EE\prime})^\beta] = p^{EE\prime}[1 + (d^{EE\prime})^\beta] \tag{31}$$

and

$$p^{WW}[1 + (d - d^{EW\prime})^\beta] = p^{EW\prime}[1 + (d^{EW\prime})^\beta], \tag{32}$$

as well as the expressions (24) and (25) that represent the price elasticities faced by the deviating firm in both markets,

$$\varepsilon^{EE\prime} = 1 + \frac{[1 + (d^{EE\prime})^\beta]p^{EE\prime}}{[p^{EE\prime}\beta(d^{EE\prime})^{\beta-1} + p^{WE}\beta(d - d^{EE\prime})^{\beta-1}]d^{EE\prime}} \tag{33}$$

and

$$\varepsilon^{EW\prime} = 1 + \frac{[1 + (d^{EW\prime})^\beta]p^{EW\prime}}{[p^{EW\prime}\beta(d^{EW\prime})^{\beta-1} + p^{WW}\beta(d - d^{EW\prime})^{\beta-1})d^{EW\prime}}. \tag{34}$$

An important remark is in order when analyzing the deviation condition. Whether we consider one firm in a particular industry and city-region deviating or all firms in that industry and city-region deviating, the expressions do not change. One reason is that the incentive for an Eastern firm to deviate only depends on its two Western-produced neighboring varieties. Another reason is that each industry is measure zero, so that even if all firms in a given industry and city-region deviate, this has no effect on aggregate income. For this result to hold, we assume that the switch to the new technology by a deviating Eastern firm does not completely wipe out the Eastern demand for the varieties of its Western neighbors.[9]

When are firms more likely to deviate and adopt the modern technology? The following result states that larger markets, lower transport costs and shorter inter-city distances increase the profitability of deviating.

Result 1. *Starting off in an equilibrium where all firms use the artisanal technology, an increase in population, a drop in transport costs and a reduction in inter-city distances all increase the incentives of an individual firm to switch to the modern technology.*

We here limit ourselves to providing some intuition, which we will further explore in the numerical section of the paper. In a similar model, Desmet and Parente (2010) show that bigger markets and lower transport costs increase the incentives to deviate. To see the rationale for this result, we start by focusing on the importance of market size, and later discuss the role of transport costs and distance. The key insight is that as the population increases, Hotelling-Lancaster preferences imply a less-than-proportional increase in the number of varieties, in contrast to what occurs when preferences are of the Spence-Dixit-Stiglitz type, where the number of varieties increases proportionally with population. The implied positive relation between market size and firm size emerges because as more varieties enter the market, neighboring varieties become more substitutable, leading to an increase in the price elasticity of demand. The result is a drop in markups, so that each differentiated good producer must become larger to break even. This increase in firm size favors adoption, since a firm can now spread the fixed adoption cost of the modern technology over more units. The deviation condition (30) is thus more likely to be satisfied for larger city-regions.

A drop in transport costs has a similar effect on the incentives to adopt the modern technology because it leads to greater competition between neighboring varieties, and thus to lower markups and larger firms. It is important to note that decreasing the geographic distance between city-regions is equivalent to lowering transport costs. Hence, having city-regions more closely spaced also increases the incentive for firms to switch to the modern technology.

[9]This could happen either because transport costs are very high, or because competition between neighbors is very strong.

3.2.2 Guilds

We now analyze whether skilled workers in a given industry and city-region have an incentive to form a professional guild, the purpose of which is to block the introduction of the modern technology in their industry. As we already discussed, there are of course many other reasons why in reality guilds might have formed. We can therefore rephrase the objective of our theoretical analysis of guilds as follows: if skilled workers in a given industry and city-region did not form a guild before for some other reason, do they have an incentive to do so with the objective of resisting the adoption of the modern technology?

A guild, should it form, is industry- and city-specific. By this we mean that all firms in a given industry and given region must abide by the guild's directives over the choice of technology. An important implication is that an industry guild in the East has no power over the action of firms in the same industry in the West. A given industry in a given city-region, therefore, will either have a professional guild or not have a professional guild. Should it face a guild, no firm in the industry and city-region can use the modern technology unless the firm or the industry can pay off the guild members by maintaining their original wages. In that case, the guild no longer has a reason to exist, and it disbands.

The starting point for our analysis is a symmetric equilibrium where only the artisanal technology is available. Specifically, we find the prices and allocations that satisfy all the conditions in the definition of the *ARTSE*. Hence, the skilled workers in each industry in a given city-region associated with this equilibrium constitute the set of potential guild members and the number of varieties associated with this equilibrium constitute the set of firms that are subject to the guild's rules. As there is measure L of workers in each region, of which $1-\mu$ are skilled, and measure one of industries in each region, then the size of any guild that forms in industry i and city r, G_i^r, is $(1-\mu)L$.

A group of skilled workers in a given industry and region will form a guild if at least one firm would find it profitable to use the modern technology and if the industry profits if all firms were to adopt are too small to compensate skilled workers for lost wages.[10] The first condition is simply the deviation condition (30). Clearly, if the first condition is not met, then no industry would have a guild for the simple reason that skilled workers are not at risk of earning lower wages.

[10] From our discussion before, recall that the condition for one firm deviating or all firms deviating is the same.

As such, they have nothing to gain from forming a guild. As a result, no guild forms and the artisanal technology prevails. The second condition says that the profits from adoption are not enough to compensate the skilled workers, so that

$$\frac{V_i^{E*}\Pi_i^{E'}}{G_i^{E*}} + w_a^{E*} \leq w_x^{E*}. \tag{35}$$

Notice that (35) makes two implicit assumptions about how losers are compensated. First, the transfers to the skilled workers are financed by the profits of the industry that switches to the modern technology. This compensation mechanism could be interpreted as being the outcome of either a bargaining process between the industry and the guild or a tax on industry profits. The latter interpretation is not unlike the poor laws which were financed locally by taxes on the wealthy.[11] Second, there are no labor market frictions, so that displaced skilled workers can immediately find employment as an unskilled worker in the economy. If we were to allow for the possibility of unemployment, the existence of poor relief would become even more important, as the expected income of the skilled worker would fall below that of the unskilled.

When it is profitable for at least one firm to adopt but industry profits are too low to fully compensate the losers, the skilled workers in an industry have an incentive to form a guild and prevent the use of the modern technology. In this case, we refer to the economy's symmetric equilibrium as a *Symmetric Artisanal Equilibrium with Guilds (GARTSE)*. Formally,

Definition of Symmetric Artisanal Equilibrium with Guilds. *A Symmetric Artisanal Equilibrium with Guilds (GARTSE) satisfies the same conditions as ARTSE, with two differences: (i) the deviation condition (30) is satisfied, and (ii) the profits of a deviating industry in a city-region are not enough to payoff their skilled workers, i.e., (35) is satisfied.*

Importantly, the prices and allocations in the *GARTSE* coincide with those in the *ARTSE*. The set of skilled workers, by forming a guild, are therefore able to sustain the same equilibrium allocations and prices as before.

Given our discussion, we would expect guilds to arise when market size reaches a certain threshold. This happens when the profits from adopting the new technology are positive, but not sufficient to compensate the original skilled workers. That is, conditions (30) and (35) hold.

[11] Strictly speaking, in our model the deviating industry would be the only one making profits, so that the limit on tax revenues from profits would be total profits, as in (35).

Equivalently, guilds will appear when transport costs drop below a certain level, or when the distance between city-regions is not too large. Of course, once profits become large enough so that (35) is no longer satisfied, guilds stop resisting and disband. In light of the above logic, we would expect this to happen if the size of the market continues to grow, transport costs fall further or the distance between cities becomes even shorter. However, as we now show, an increase in market size is *by itself* not enough for guilds to disappear. Hence, the spatial distribution of city-regions, in addition to their sizes, is essential for the downfall of the guilds.

3.3 Market Size, Spatial Competition and the Demise of Guilds

In this section we show that spatial competition is key for resistance to break down and the economy to take off. More particularly, in the absence of trade between cities, an increase in market size is never enough to lead to the demise of guilds. The intuition for this result is as follows. Suppose the economy is in a symmetric artisanal equilibrium with guilds *(GARTSE)*. For the guilds to disappear, the industry's profits from deviating must be enough to compensate the industry's original skilled workers. These profits come from stealing business from others. When there is trade, an industry can steal business from the same industry in the other city-region; however, in the absence of trade, it can only steal business from itself, so that deviating never leads to profits. We now formally state and prove this result.

Result 2. *For an economy in GARTSE that faces prohibitive trade costs, an increase in population will never lead to the violation of (35), so that guilds will never disband.*

Proof. Start from an equilibrium where all firms use the artisanal technology. Firms make zero profits and all the firms' earnings are paid out to the industry's (skilled) workers. Now suppose all those firms switch to the modern technology. Because household preferences are Cobb-Douglas across industries, the total income spent on a given industry's varieties is independent of the technology it uses. Since there is no trade, all the income is spent on the local industry, both before and after the adoption of the modern technology. Hence, switching technologies does not affect an industry's total earnings. Since all earnings before the technology switch were going to the industry's original workers, it is impossible to make all those original workers better off when adopting the modern technology. Hence, (35) is never violated, and guilds never disband. □

An important implication is that market size *per se* is not enough for guilds to disband and innovation to take off. As stated in the following result and as our numerical simulations will clarify, the same argument does not hold once trade costs between city-regions are no longer prohibitive.

Result 3. *For an economy in GARTSE that faces non-prohibitive trade costs, an increase in population or a decrease in inter-city transport costs may lead to the violation of (35), so that guilds disband.*

Result 3 is of course nothing else than a corollary of Result 2.

The assumption that guilds operate at the city-region level rather than at the national level is the key to understanding the role of trade. Consistent with historical evidence, in the model a guild's power does not transcend the boundaries of its own city-region. As a result, in a multi-city model, when an industry in a given city switches to the new technology, it only needs to compensate its skilled workers in its own city, and it can increase its revenue (and profits) by stealing business from firms in the other city. The business stealing effect between cities is greater when either the market size increases or transport costs between cities drop. But there will not be any business stealing in the absence of trade.[12]

As our discussion above emphasizes, and our numerical experiments will further clarify, the role of market size on innovation is subtle. In a world where cities are geographically too isolated to trade with each other, increasing population size never leads to industries switching to the modern technology. In contrast, if there is trade across cities, then increasing population size or decreasing trade costs makes it more likely for innovation to occur. Hence, having a sufficiently large market is never a sufficient condition for countries to industrialize. Instead, it is a favorable spatial organization of economic activity, with cities located fairly close to each other, together with those cities being large, that provides the adequate conditions for guilds to weaken and industrialization to take off.

4 Calibration Exercise

In this section we calibrate the model to the evolution of spatial competition in England in order to assess the plausibility of our theory. More specifically, we parametrize the model to match the date when guilds in England started to block the introduction of labor-saving technology using the

[12]Note that in a setup where industries are large or where the elasticity of substitution between industries is greater than one, there would not be such a sharp distinction between a situation with trade and one without trade, although the qualitative insights would not change.

historical data on spatial competition described in Table 1 in the pre-blocking period. Then, to test the plausibility of our theory, we derive the predictions of the calibrated model for the date at which guilds in England should have given up. We find that the model predicts well the actual timing of the end of resistance.

4.1 Parametrization

For the date at which guilds in England started blocking labor-saving technology we use the year 1600. As discussed above, guilds actually appeared much earlier, but initially they functioned mainly as benevolent societies that provided public goods to their members. It is only later, in the seventeenth and eighteenth centuries, that they regularly exhibited resistance to labor-saving technologies. Since in our theory craft guilds have the single function of blocking the adoption of labor-saving technologies, the relevant start date is when they begin resisting, rather than when they first appear.

Rather than focusing on when the modern technology became available, we are interested in when the modern technology became attractive for firms to adopt. In undertaking the calibration exercise, we therefore assume that the modern technology is available in all periods, and interpret 1600 to be the date when firms start finding it profitable to innovate but face guild resistance. That is, we calibrate the model to yield the $GARTSE$ in 1600 and the $ARTSE$ prior to 1600.[13] To be more precise, prior to 1600 no guilds exist for the purpose of blocking the introduction of the modern technology as no firm finds it profitable to introduce it. Around 1600 guilds form as the modern technology generates positive profits but not sufficiently large to buy out the skilled workers in the industry. The underlying calibration strategy consists in restricting parameter values so that guilds form when the degree of spatial competition intensifies to the actual level that existed in England in 1600. Without loss of generality, the starting date used in the calibration is chosen to 1400.[14]

The test of the theory then involves determining the first date when the $GARTSE$ fails to exist. This is the date when industry profits are large enough to compensate the skilled workers

[13] Since we assume that the modern technology is always available, the definition of the $ARTSE$ now requires the additional condition that no firm in no industry has an incentive to adopt the modern technology, i.e., $\Pi^{E\prime} \leq 0$.

[14] Although the above explanation of the general strategy underlying the calibration refers to specific dates, they are actually irrelevant when it comes to the actual assignment of parameters. More to the point, it is the degree of spatial competition at various dates that matters in restricting the parameter values.

for their reduced earnings. At that point, guilds stop resisting, and the economy takes off. To that purpose, we feed the data on city sizes and inter-city distances into our calibrated model, and determine whether the model predicts that guilds stop resisting when spatial competition reaches the level observed in England in 1835, the year in which guilds were abolished.

Table 3: Parameter Values

Parameter	Target/Comment
1. Endowments	
$L_{1400} = 116$	Average firm size of approximately 1.75 in 1400
$\mu = 0.925$	Fraction of non-urban population in 1600
2. Transport costs	
$\tau_{1400} = 0.09$	Willan (1976), Masschaele (1993) and Munro (1997)
$\tau_{1600} = 0.07$	Drop in average distance between same-size cities (Table 1)
$\tau_{1835} = 0.02$	Drop in average distance between same-size cities (Table 1)
3. Preferences	
$\alpha = 0.097$	Urban-rural real wage premium of 33% between 1400 and 1600 (Clark 2001)
$\beta = 0.65$	Ratio of average city size between 1400 and 1600 (Table 1)
4. Technologies	
$\Gamma_a = 1.0$	Normalization
$\Gamma_v = 1.0$	Normalization
$\gamma = 1.5$	Productivity gains in textile (Randall, 1991)
$\kappa = 0.25$	Share of time on non-production activities of 0.12 in 1600
$\phi = 3.5$	20% rate of return earned by Bean Ing Mill in 1792-99 (Hudson 1986)

The parameter values are shown in Table 3. As our model structure is not commonly used in the growth literature, it is useful to explain in some detail how each parameter value was chosen. Starting with the parameter values listed under the endowment category, we set the average city size in 1400 as to generate an average firm size of around 1.75 workers. The target for the average firm size is based on the idea that artisanal shops in the fifteenth and sixteenth century consisted of either a craftsman on his own or a craftsman and an apprentice. The obvious question is why we did not set the population to reflect the actual 1400 average city population in England. The short answer is that theoretically city size only matters to the extent that it affects firm size, so the relevant target is the firm size. Alternatively, we could have adjusted the circumference of the circle to make the firm size consistent with the actual city size. This would not change anything, but it would come at the cost of introducing one more parameter, so we refrain from doing so. The second endowment parameter, μ, requires far less explanation. As it represents the fraction of the population that is unskilled, its value is set to the fraction of the rural population in England in

1600.

Turning to the iceberg transport cost, its value is based on several studies that provide estimates of transport costs as a fraction of total costs in pre-industrial Europe. Taking an average over a variety of goods, we find a cost of 0.1% per km.[15] To get a measure of inter-city transport costs, we need to multiply this number by the average distance between cities. In the context of our model, the appropriate distance measure is S_3, the average distance for a city to reach the same number of consumers as its own city. As reported in Table 1, in 1400 that average distance was 93 km, so we set $\tau_{1400} = 1.09$. The 1600 and 1835 values are chosen based on the decline in the average distance to same-sized cities. From Table 1 we know that S_3 dropped to 70 km in 1600 and to 21 km in 1835, so that $\tau_{1600} = 1.07$ and $\tau_{1835} = 1.02$.

Moving on to the preference parameters, the assignment of the expenditure share on the industrial goods in the household utility function, α, is straightforward. Given the fraction of unskilled households, the expenditure share parameter is set so that the wage differential for skilled to unskilled workers in the *ARTSE* matches the urban-rural wage premium in England between 1400 and 1600 based on data from Clark (2001).[16] The assignment of the curvature parameter of the Lancaster compensation function, β, requires greater explanation as it is one of the parameters specific to our Hotelling-Lancaster preference structure. To calibrate it, we exploit the fact that the curvature parameter is critical for determining the city size threshold for when resistance starts.[17] For this reason, we set β so that the *GARTSE* first exists when the average city size in the model exhibits the same increase as the one experienced by England between 1400 and 1600, using the calibrated iceberg costs in those two years.

The last set of parameters are related to the technology. As shown, the TFP parameters

[15] We base our estimate on information on four different goods: grain, wine, luxury woolens and semi-worsted woolens. Masschaele (1993) finds that transporting grain in 14th century England added around 0.25% per km to the price. Based on data from the end of the 16th century, transporting wine from Chester to Smithills increase the price by 0.17% per km (Willan, 1976). As for woolen products, Munro (1997) cites different studies. One is based on the writings of a Flemish merchant who exported luxury woolen from Bruges to Barcelona in the late 14th century at a cost of 0.02% per km. Another study reports a cost of around 0.01% per km for semi-worsted woolen products exported from Caen to Florence in the early 14th century. Taking these four numbers, the average transport costs was around 0.1% per km.

[16] Clark (2001) reports wages for urban craftsmen, urban laborers and farm laborers. We estimate the urban wage to be the average of the wages of the urban craftsmen and the urban laborers. We then define the urban-rural wage premium as the ratio of urban to rural wages. We adjust this ratio for the cost of living differences between urban and rural area by using the relative wage of laborers in both places.

[17] A decrease in the value of β, i.e., more curvature, makes it harder for an innovating firm to steal away consumers who are closely located to their nearest neighbors on the variety circle. This implies that firms have less of an incentive to adopt the modern technology, thus increasing the threshold for when resistance starts.

in agriculture, Γ_a, and in industry, Γ_v, are both normalized to 1. Because of the Cobb-Douglas nature of preferences between the agricultural good and the industrial goods, any change in relative productivities translates into changes in relative prices, leaving expenditure shares unchanged. From that point of view, the TFP parameters do not affect the market size of the industrial sector, so we can normalize both to one. For the parameter γ, which governs how much more productive the modern technology is relative to the artisanal technology, we set its value to 1.5, consistent with the reduction in the time input of men making woolen cloth between 1781 and 1796, as summarized by Randall (1991).[18] The fixed operating cost parameter, κ, is targeted so that skilled workers spend between 10% and 15% of their working time on non-production activities in the *ARTSE*. We are not aware of any historical study documenting the amount of time industrial workers spent in the fifteenth and sixteenth centuries on non-production activities. Absent such evidence, we thought that time allocations in this range were reasonable.

This leaves the assignment of the fixed innovation cost parameter, ϕ. Because the calibration is done so that no firm would introduce the modern technology before 1600, we cannot use observations from this period to tie down a value. What is needed is an observation associated with an actual deviation, where a firm first introduced the modern technology. A good example could be the establishment of a textile mill, using information on actual resource expenditures associated with the mill or rate of return on the millowner's investments. Hudson (1986) reports rates of return earned by a number of textile mill owners in the late eighteenth century, with John Gott and his Bean Ing mill being the earliest listed. We use the average of the earliest period reported returns in Table 8 of Hudson (1986) for John Gott's mill, setting it equal to the implicit rate of return on fixed cost expenditures in our model, defined as $\Pi^{E\prime}/[w_a(\phi+\kappa)]$. This completes the calibration of the model.

4.2 Test of the Theory

After having calibrated the model to England between 1400 and 1600, we analyze its predictions for when resistance should have broken down. Specifically, we now assume the iceberg cost takes on its 1835 value, τ_{1835}, and then consider increases in average city size. For each city size, we determine if the conditions of the *GARTSE* continue to be met, and mark the first city size were

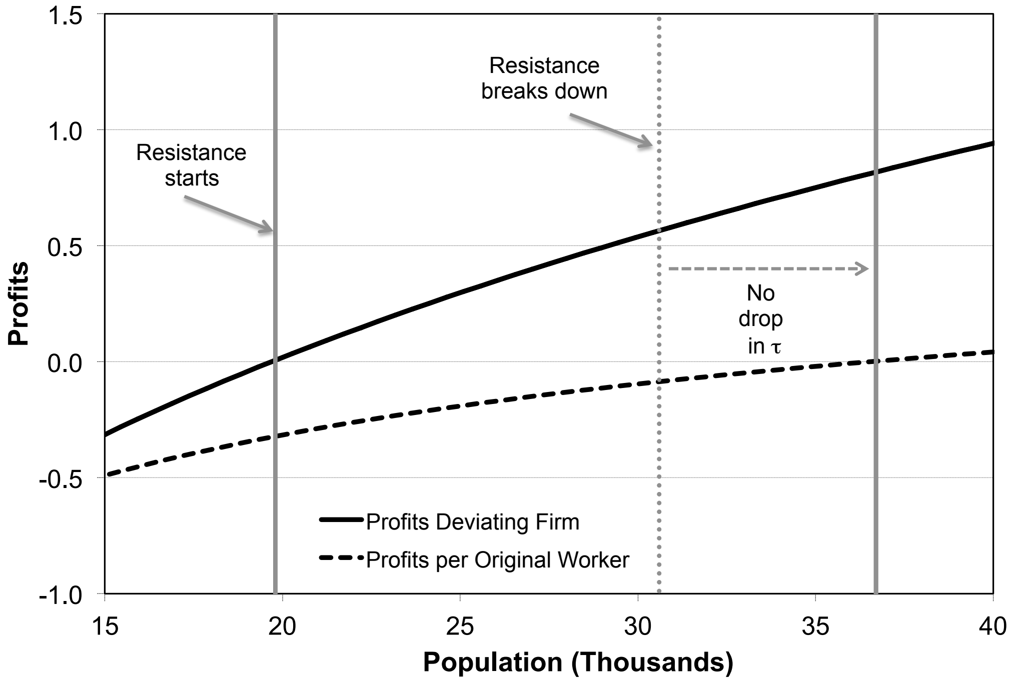
[18]See Randall (1991, p. 52.-55) for estimates of the labor requirements for making a piece of superfine broadcloth between 1781 and 1828.

it is violated. We compare the ratio of this average city size to L_{1400} to the actual ratio in the data. For resistance to have broken down in 1835, the calibrated model predicts that the average city size in 1835 relative to the one in 1400 is 2.8. Going back to Table 1 and assuming a constant growth rate of city size between 1800 and 1850, the average city size ratio for England between 1400 and 1835 is 2.7. From this we conclude that the increase in spatial competition in England between 1400 and 1835 can account for England's take-off.

To provide some additional perspective on how important the increase in spatial competition was for England's early industrialization, we perform the following counterfactual experiment. We determine the city size needed for resistance to break down had the iceberg cost parameter τ remained at its 1400 value of 1.09. That is, we predict how much bigger English cities would have had to be before guilds gave up if inter-city distance had not declined between 1400 and 1835. For $\tau = 1.09$, Figure 1 shows two profits curves as a function of a city's population. The first one represents the profits of an individual firm that deviates from the *ARTSE* and adopts the modern technology. The second one represents the wage increase that skilled workers receive if all the profits from deviation are rebated to the original workers. More specifically, the latter measure is defined as the industry profits when all firms switch to the modern technology divided by the original skilled workers in the industry less the agricultural wage rate. The two solid vertical lines represent the two thresholds. The first threshold corresponds to the city size when it becomes profitable for a firm to deviate and adopt the modern technology; the second threshold corresponds to the city size when guild members can be duly compensated so that resistance breaks down.

To facilitate comparison to the actual data, we convert the normalized city size in 1400 to the actual average city size in 1400. In the absence of a decline in inter-city distances, the model predicts that guilds form when a city size of 20,000 is reached, and they end their resistance when a city size of 37,000 is reached. Compared to the benchmark, where we do take into account the drop in τ, guilds form when the average city size reaches 19,000 and they give up when the average city size reaches 31,000. In light of the counterfactual predictions above, it would appear that the decline in inter-city distance over the period 1400-1835 in understanding England's take-off was quantitatively not that important. Instead, the main force for ending resistance seems to have been the increase in city size. In retrospect, this result should not be seen as surprising. Inter-city distances in England were already quite low in 1400, so that the further decline in distance only had a modest impact on ending resistance.

Figure 1: City Size in England: Resistance to Technology Adoption



This does not mean that spatial competition did not matter. Indeed, when inter-city distances are short, the increase in city size has an important effect on the degree of spatial competition. Nor does this imply that changes in inter-city distances are never important to understand industrialization. As will become apparent in the set of experiments conducted in the next section, it may matter immensely: England was fortunate in starting out with cities located in short proximity to each other. China, in contrast, was not so fortunate.

5 Spatial Competition and the Great Divergence

Now that we have established that the theory is able to account for the timing of the breakdown of resistance in England, we further explore the model's plausibility by analyzing its predictions for China's development path. In particular, we are interested in seeing whether it can contribute to our understanding of the *Great Divergence.* To that end, we will feed data on city sizes and inter-city distances in China into our calibrated model. Before doing so, we show that there were important differences in spatial competition between China and England, and we provide a brief overview of the history of guilds in China.

5.1 Spatial Competition in China

In this section we document the important disparity in the degree of inter-city competition between China and England.

5.1.1 Data

The most detailed data on city populations in China come from Yue, Skinner and Henderson (2007). The data is for a single year, 1893, and includes all 2403 cities that served as administrative capitals of prefectures or counties during the period 1820-1893. Rather than providing the exact population of each city, cities are identified by 11 size classes. Starting with populations of less than 500 for the lowest size class, the upper limit of each size class is defined to be twice its lower limit, until reaching 512,000. That is, classes consist of: less than 500; 500 to 1,000; 1,000 to 2,000; 2,000 to 4,000; ...; 256,000 to 512,000; and more than 512,000. Except for the highest class, we use the mid-value value of each class to define the size of a city's population. For the highest class, we use city population data of 1900 from Eggimann (1999) to assign populations.[19]

Using these population estimates, we compute China's urbanization rate in 1893. To make our calculation comparable to existing estimates, we focus exclusively on cities with a population of more than 10,000. Taking the total population of China to be 386 million in 1893 (Maddison, 2001), this yields an urbanization ratio of 7.5 percent. This is much higher than the 4.4 percent consensus figure, dating back to Rozman (1973) and widely used in the literature (Broadberry and Gupta, 2006; Maddison, 2001). One reason for this discrepancy is that many of the administrative capitals of counties (rather than prefectures) are not cities in any real sense. If we restrict our attention to prefecture-level cities that appear in Cao (2000), rather than to the larger set of locations in Yue, Skinner and Henderson (2007), we get an urbanization ratio of 4.7 percent, in line with the estimates of Rozman (1973). We therefore use this subset of cities as our benchmark, although we will conduct robustness analysis with the broader set of cities in Yue, Skinner and Henderson (2007). To make our analysis for China comparable to that for England, we also include cities with a population between 5,000 and 10,000.[20]

To obtain city size estimates for China prior to 1893, we take the following approach.

[19]Note that we cannot use Eggimann (1999) as an alternative source for our overall study of urbanization in China because of the high number of missing data: for 1850 Eggimann (1999) only has data on 62 Chinese cities, and by 1900 that number has only increased to 85.

[20]Of course, this implies a higher urbanization rate.

Cao (2000) provides prefecture-level population data for 1776, 1820, 1851, 1880 and 1910. These population data refer to the entire prefectures, and not to the urban part of the prefectures. To get population estimates for the urban parts of the prefectures, we take the relative growth rates of cities to be equal to the relative growth rates of their corresponding prefectures, and we set the absolute growth rate of the urban population in China to match the country's urbanization ratios in 1776 and 1820 as reported in Rozman (1973). Between any two dates in Cao (2000), we assume growth rates of prefectures do not vary over time. Using this methodology, we get estimates for Chinese cities with a population of more than 5,000 in 1776 and 1820. In order to compare China and England, note that for England we have imputed population values for 1776 and 1820, assuming that city-specific growth rates between two consecutive years in the Bairoch et al. (1988) dataset were constant.

We also provide imputed estimates of city sizes in 1700. Since the urbanization rate in China did not change between 1700 and 1820 (Maddison, 2001), we assume that each city in China grew at the same rate as the overall population between 1700 and 1820. Of course, these estimates should be interpreted with some caution, but they provide a rough idea of China's urban structure at the beginning of the century that saw the start of the *Industrial Revolution*.

Market size and city size. Before documenting the differences in spatial competition between England and China, it is useful to briefly analyze the data on market size and city size. Panel A in Table 4 reports the total population size of England and China between 1600 and 1900. To facilitate comparison, we also show the numbers for England, although some of them have already been reported in Table 1. In both countries the population increases over time, with China being 20 to 40 times larger than England, depending on the time period. If, instead, we focus on the urban population as the relevant measure of market size, Panel B shows China is still much bigger than England. Rather than comparing China to England, we could focus on Northwest Europe, the broader region to first industrialize, as the relevant counterpart of China.[21] Although the differences become obviously smaller, China is still larger than Northwest Europe, in terms of both its total population and its urban population. Panel C reports average city sizes in England and China. In both countries average city size increased over time, whereas at any point in time, average city size was greater in China than in England. In 1700 the average Chinese city had a population of 33,700,

[21] We take Northwest Europe to be Great Britain, France, Belgium, Netherlands and Germany.

Table 4: Spatial Competition: England and Northwest Europe vs China

Year	1600	1700	1776	1800	1820	1850	1893
A. Total Population (millions)							
England	4	5		8	10	15	24
China	160	138		381	412	386	
B. Urban Population (millions)							
England	0.3	0.9	1.5	2.6	3.8	7.0	
China		5	11.3		14.4		18.4
C. Average City Size (thousands)							
England	19.1	25.1	30.5	21.2	30.3	50.8	
China		33.7	57.2		66.1		77.0
D. Population access $\leq$ 20 km (S_1, thousands)							
England	0.0	1.3	26.6	73.8	107.2	190.6	
China		2.9	5.2		6.1		5.7
E. Population access, spatial decay $\delta = 1.5$ (S_2, thousands)							
England	0.2	0.6	1.5	4.1	6.1	11.6	
China		0.9	1.8		2.2		2.7
F. Distance to reach same number of consumers (S_3, km)							
England	70	44	37	21	21	21	
China		181	173		164		157

around 35% larger than the average English city. In later periods, that difference increased, with Chinese cities becoming more than twice the size of English cities. Taking into account that England and China had similar levels of income per capita in the Early Modern period, this suggests that market size alone is an unlikely explanation for why England industrialized first. In what follows we turn to comparing the degree of spatial competition in the two countries.

5.1.2 Measures of Spatial Competition

Panel D reports the population access in a radius of 20 km, what we referred to as measure S_1^r. In 1776, around the time of Adam Smith's scything critique of the English craft guilds, market access of the average English city was about five times that of the average Chinese city. By 1820, when English craft guilds were severely weakened and about to be abolished, that advantage had risen to an 18-fold difference. At the end of the nineteenth century, market access of the average Chinese city was similar to that of the average English city 150 years earlier. Panel E reports S_2^r, the distance-weighted access to population. As before, the spatial decay parameter γ is 1.5. Although the difference between England and China is less stark, in the early nineteenth century, when resistance to innovation broke down in England, market access was between two and three times larger in England. Lastly, Panel D shows the average distance to reach the same population as in the own city, our preferred measure of spatial competition. In China the average distance to reach the same number of consumers started off being about four times larger than in England, and by the end of the nineteenth century it reached a number more than seven times larger than in England.

These different measures show that whereas the degree of inter-city competition increased dramatically in England between 1600 and 1900, it only slightly increased in China. This suggests that the capacity of the average English city to steal business from its close-by neighbors was much stronger than that of the average Chinese city.

5.2 Guilds in China

The history of guilds in China is far less known than their history in England and Europe. There are many parallels, but also many differences. In China, there were also two types of guilds, the *huiguan* and the *gongsuo*. The *huiguan* were native-place guilds whose members came from a specific region and were often, but not always, engaged in the same craft. The *gongsuo,* in contrast, were city- and profession-specific. Though not identical, we can think of the *huiguan* as being the Chinese counterpart of the European merchant guilds, and the *gongsuo* as being the counterpart of the European craft guilds. In terms of what we call guilds in our theory, the *gongsuo* is the relevant institution. We will nevertheless briefly start by discussing the *huiguan* in our chronological description of guilds in China.

Fifteenth century China and England differed much in terms of their political and social structures. Although politically unified, China was an empire consisting of socially and culturally distinct areas in which kin-based organizations (particularly clans) and other local groups were self-governed. Yet, travel to far-away administrative and commercial centers was often necessary and rewarding and those who traveled organized themselves according to their place of origin to assist each other during their stay. These native-place organizations that served to mutually assist its members were called *huiguan, hui-kuan* or *tung-hsiang-hui* (meaning "assembly" or "club-houses"). Although many of the names of the *huiguan* referred to some province, membership was usually confined to a smaller area, such as a county, a city, or a few villages. These *huiguan* shared some similarities with European merchant guilds in that they facilitated long-distance inter-regional trade (for China see, e.g., Shiue and Keller, 2007, and Moll-Murata, 2008; for Europe see, e.g., Gelderblom and Grafe, 2010).

The more relevant point for our theory is that although the *huiguan* exerted strict control over its members, in general they did not monopolize specific sectors, and therefore are different from what we call guilds in our model. In a city such as Beijing, there would not have been *one* cloth guild controlling the entire industry, but rather many different *huiguan*, representing different regions in China, many of which might have had some presence in the cloth industry. Consistent with this, in their heyday, there were up to 400 *huiguan* in Beijing alone (Rozman, 1973). In that sense the *huiguan* did not impede within-sector competition in Chinese cities. If anything, in their early days the *huiguan* enhanced competition by counteracting the monopolistic power of the government-appointed headmen (*hangtou* or *hanglao*) who set prices in different crafts and trades.

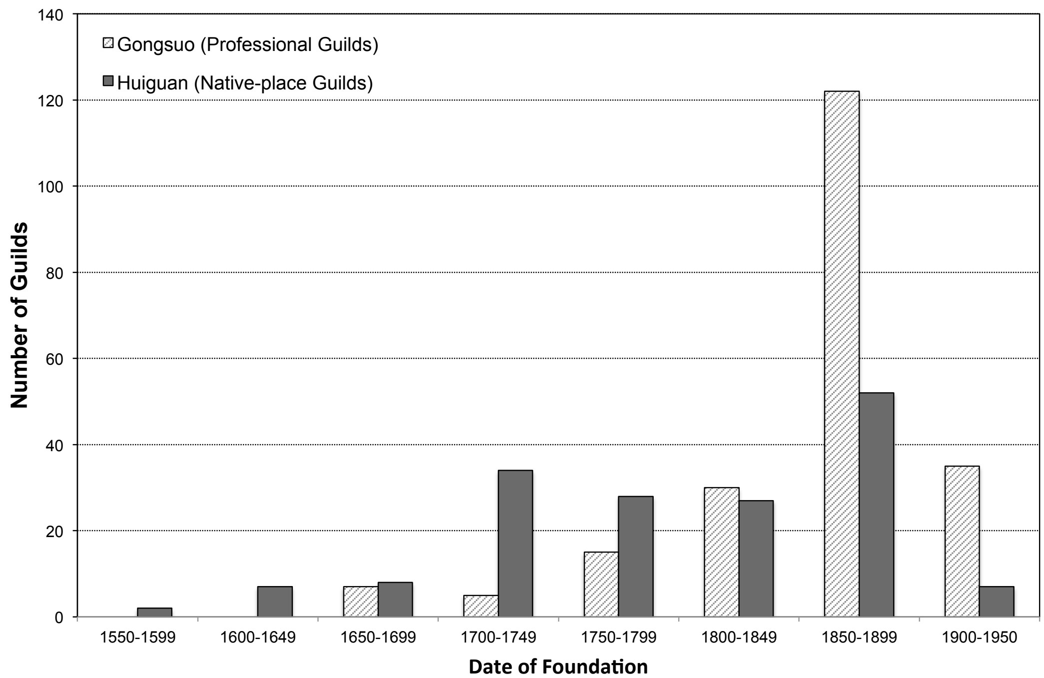
Similar to the European merchant guilds, the prevalence of the *huiguan* diminished over time. The transition began in the late seventeenth century, evolving into a system in which European-style, occupation-based local craft guilds dominated. Those newly-created occupation-based guilds were referred to as *gongsuo*, literally meaning "public hall" or "meeting place" (Moll-Murata, 2008). There is no simple way of dividing Chinese guild history into a *huiguan* and a *gongsuo* period. Using data from Moll-Murata (2008), Figure 2 shows the relative evolution of *huiguan* and *gongsuo* by their founding period.[22] As can be seen, the big push towards *gongsuo* is associated with the second half of the nineteenth century. This coincides with a growing European presence in the region following the Opium Wars, and an increasing availability of imported European labor-saving technologies. In terms of our theory, the emergence of guilds in China should thus be situated in that time period.

Similar to Europe, the *gongsuo* emerged earliest in the largest cities. Between 1650 and 1700 the first *gongsuo* appeared in cities such as Beijing, the country's capital, and Suzhou, an important inland port city in Jiangsu province. Between 1780 and 1850, a total of twelve *gongsuo* were established in Suzhou, including those of tailors, hatters, cabinet-makers, tanners, and butchers. The Chinese *gongsuo* pursued policies similar to the European crafts guilds prior to the latter's decline.[23] The *gongsuo* provided public goods and regulated production, prices and trade. Although

[22]The database contains 516 named pre-1900 guilds of which 347 can be classified as either common origin or common occupation.

[23]The Great Guild of Newchwang, for example, was composed of all the merchants and bankers in this city port. It regulated quality and prices and punished any member who cut rates. Only members and those whom they invited

Figure 2: Native-place *(huiguan)* vs Professional *(gongsuo)* Guilds by Date of Foundation in China



early on the *gongsuo* did not acquire the same judicial authority over their trade as European craft guilds did, they were *de facto* very effective in monopolizing professions. The evidence reveals that they "establish rules and compel obedience to them; they fix prices and enforce adhesion; they settle or modify trade customs and obtain instant acquiescence; they impose their will on traders in and out of the gilds [sic], and may even, through the measure known as the 'cessation of all business' cause the government to modify or withdraw its orders; and their end, that of having the absolute control of their craft, is obtained by methods of which some are indicated above" (Morse, 1909, p. 31). The *gongsuo* thus obtained "an enormous and almost unrestrained control over their respective trades" (Morse, 1909, p. 21).

Compared to their European counterparts, Chinese guilds were more successful at restricting trade. One observer of China remarked, for example, that "it is not too positive to write, that it is within the power of the guilds to interfere with commercial intercourse in China, to seriously impair the commercial relations of Western nations with China, and to comparatively drive from the trade markets of the Empire the foreign products now sold in those markets, or to make the demand

were allowed to be active in the money markets. The guild regulations stated that "visitors, however, shall not be allowed to bid in the market, and all their business must be transacted through a member" (Morse, 1909, p. 51). Other guilds in that city controlled the grain, fuel, and straw markets.

for them so unremunerative as to partially destroy importation, while the Central Government, if it had the inclination or the means, would scarcely have the courage to remove the organized obstruction or to punish the obstructors" (Jernigan, 1904, p. 103).

The strict control that the *gongsuo* imposed on their members could not but hinder innovation. The guilds were particularly active in preventing competition from the introduction of new, labor-saving innovations, as noted, for example, in a first hand account by MacGowan (1886)

> Native merchants imported from Birmingham a quantity of thin sheet-brass for manufacturers of brass utensils at Fatshan, throwing out of employment a class of coppersmiths whose business consisted in hammering out the sheets heretofore imported in a thick form; but the trade struck to a man, would have none of the unclean thing, and to prevent a riot among the rowdiest class of the rowdiest city in the empire, the offending metal was returned to Hongkong. Further, a Chinese from America the other day imported thence some powerful sewing machines for sewing the felt soles of Chinese shoes to the uppers, but the native sons of St. Crispin destroyed the machines, preferring to go on as their fathers did, while the enterprising Chinaman returned to Hongkong, a poorer and sadder man. Again, some years ago a progressive Chinaman set up a steam-power cotton mill, only to be made useless by the very simple plan of the growers refusing to send in a pound of cotton. Filatures from France, effecting not only a wonderful saving in time and money but improving the quantity and quality of the output of silk, succeeded at Canton for a while, and were introduced latterly by Chinese capitalists into the silk-rearing districts, only to be destroyed and wrecked by the country-folk" (p. 183).

The evidence reveals that adoption of labor-saving machinery was hindered by the threat of social disorder due to the job loss. One such piece of evidence is contained in a report sent from China to the Foreign Office in London and it concerns the mechanization of cotton cloth production in Shanghai in 1876.

> During the past year [1876] an attempt was made to launch a Steam Cotton-Mill Company at this port [Shanghai], for the purpose of manufacturing cotton piece-goods from native-grown cotton ... similar . . . to the goods at present made by Chinese . . . but with

> the advantages of English machinery and steam-power, ... When the enterprise came to be generally known to the Chinese newspapers, the attitude of the Cotton Cloth guild became so alarming that the native supporters [of the project] drew back. An idea was unfortunately circulated among the natives, and more particularly amongst the workers of native hand-made cloth, that the trade would be immediately put an end to if such a scheme were put into operation, whereupon the guild passed a resolution to the effect that no clothes made by machinery should be permitted to be purchased... The local officials refused their support crown care and to the screen, through fear of causing riots among the people..." (Great Britain. Foreign Office. 1875-8. pp. 17-18 in the report for 1877).

The description makes clear guilds had the power to block new technologies. Attempts to mechanize other industries faced similar difficulties. In 1868 for example, the "fiercest resistance" to mechanizing the silk industry "came from the organized silk handicraft and commercial guilds" (Ma, 2005, p. 201). The fear of riots suggests that the poor relief measures that prevailed under the Qing period were not conducive to mitigate the threat to social order associated with the introduction of labor-saving machinery. One such measure was the granary system, run by the state and aimed at alleviating food shortages. Another was the "clan trust", the use of common property by the kin group to assist clan members in need.[24] Compared to England, in nineteenth-century China the poor relief system was ill-equipped to face the challenges of industrialization. In addition to being in decline, the granary system was not designed to assist the poor, but rather to dampen high grain prices when harvests failed. The clan trust did help the poor, but it was confined to clan members, and hence limited to clans with sufficient resources.

During the second half of the nineteenth century, Chinese producers also experienced, for the first time, increasing competition from Western goods that were either cheaper or better than the equivalent local goods. For example, the introduction of Western-style hats reduced the demand for traditional-style hats while the local makers of the traditional brass-wash basins could not compete with the imported lighter and cheaper enameled basins (Bradstock, 1984, p. 228). By the late nineteenth century, the increase in spatial competition on the one hand and the technological

[24]For an in-depth description of these poor relief policies, see Bradstock (1984), Greif, Iyigun and Sasson (2012), Greif and Iyigun (2013) and Will and Wong (1991).

stagnation on the other were increasingly undermining the Chinese industry.[25] In terms of our analysis, spatial competition among Chinese firms and between Chinese producers and Western importers had rapidly risen. More intense spatial competition is reflected in inter-guild and inter-city economic conflicts. For example, "the satin guild in Soochow was forced to seek an injunction in 1898 against natives of Nanking who had illicitly begun making certain parts found on looms, a task which had historically been passed down from father to son among a particular subgroup within the guild" (Bradstock, 1984, p. 224).

Consistent with this timing of events, the *gongsuo* began to decline at the end of the nineteenth century during to the late Qing period, with the final ones disbanding when the Chinese communist party came to power in 1949 (Moll-Murata, 2008). The decline of the professional guilds in China coincided with the increase in inter-city competition. In the early twentieth century China's internal market became more integrated and foreign competition became fiercer. As late as 1870, there was no railroad system in China, but by 1913 there were 13,441 kilometers of railroads, greatly facilitating internal trade. By that time China had also become increasingly integrated into the world economy. While at the end of the First Opium War China opened five "treaty ports" to international trade, this number increased to 92 by 1917. As described by a spokesman for the Shanghai builders' guild in the early twentieth century, "our knowledge gradually narrows, our skills deteriorate, and our tools fall out of date. Foreigners then exploit this opportunity to export their goods to our country... The European fad comes sweeping through our country like a flood, and there is no stopping it" (Bradstock, 1984, pp. 228-9).

5.3 The Great Divergence

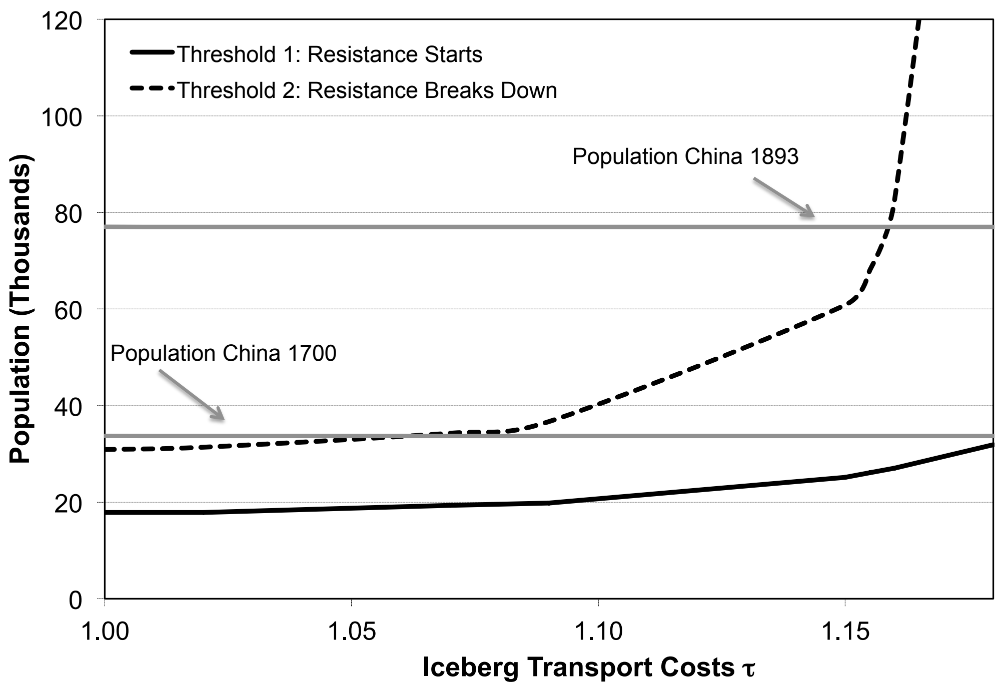
Having provided a history of Chinese guilds and having shown how their rise and decline related to the degree of spatial competition, we now explore the importance of spatial competition for the *Great Divergence* within our calibrated structure. In particular, we examine whether the greater distance between Chinese cities can explain the delay in China's industrialization.

Rather than directly focusing on the iceberg costs consistent with the average distance between same-size cities in China, we start by carrying out a more general exploration of the role of transport costs. Figure 3 plots the upper and lower city size thresholds for the calibrated model

[25] For a discussion of other reasons, such as population growth, military defeats and limited taxation capacity, see, for example, Bradstock (1984), Rosenthal and Wong (2011) and Vries (2015).

as a function of the iceberg costs, starting with $\tau = 1.0$ and ending with $\tau = 1.18$. As expected, both thresholds increase as a function of the iceberg costs. We find that the upper threshold is very sensitive to increases in transport costs. For $\tau = 1.18$, the upper threshold rapidly goes to infinity, implying that increases in city sizes no longer suffice for resistance to break down.[26] For these high iceberg costs, trade is too costly so that the profits from stealing away customers from the other city are never large enough to compensate skilled workers for reduced wages.

Figure 3: China: Resistance to Technology Adoption



What are the implications for the timing of China's development? To answer this, we use estimates of the inter-city transport costs for China in different time periods to determine the city-size threshold required for take-off to occur. Table 4 shows that the distance between same-sized Chinese cities was 181 km in 1700 and 157 km in 1893. Recall, that for England in 1400 the distance between same equal-size cities was 93 km. Given that we calibrated England's inter-city iceberg

[26] When cities become larger and the distance between neighboring varieties becomes smaller, two forces are at work. On the one hand, it becomes easier to steal away customers, because competition between neighbors strengthens. On the other hand, it becomes harder to steal away customers, because the curvature of the Lancaster compensation function when $\beta < 1$ implies that customers who are very close to their ideal variety are difficult to pull away. For relatively low values of τ, the former force dominates the latter, whereas for relatively high values of τ, the latter force dominates the former. The intuition is straightforward: higher values of τ are associated with less competition, but more varieties. Stealing away customers is harder both because competition is weaker and because more customers are relatively close to their ideal varieties. As a result, for a high enough value of τ, we find that the upper threshold goes to infinity.

trade cost to be 1.09 in 1400, the corresponding figures for China are 1.18 in 1700 and 1.16 in 1893.

As can be seen in Figure 3, for $\tau = 1.16$, the upper threshold occurs at a city size of 83,000. That is, according to the model resistance should have broken down when the average city reached a size of 83,000. From Table 4 we know that the average city size in China in 1893 was 77,000. Thus, the model predicts that China should have started to industrialize sometime in the early twentieth century. Consistent with this, guilds in China started to decline at the start of the twentieth century.[27]

Although successful in this respect, a simple interpretation of the model predicts that technology-blocking guilds should have appeared in China before 1700. For $\tau = 1.18$, the lower threshold as predicted by the model occurs when its city size reaches 32,000. Since the average city size in China was already 33,700 in 1700, this says craft guilds should have formed earlier than they actually did. Although a few *gongsuo* did form in the second half of the seventeeth century, Figure 2 shows that the big shift towards *gongsuo* happened in the second half of the nineteenth century.

This inability of the model to match the late appearance of technology-blocking guilds is not surprising. For resistance to occur, the labor-saving modern technology must first become available. Our reading of the historical evidence strongly suggests that the major labor-saving technologies in China were imported from England, and this did not happen until after the Treaty of Nanking in 1842, at the end of the First Opium War. In that sense, the question of China's late industrialization is not why it did not happen between 1750 and 1850, but rather why it failed to materialize once the country got access to modern technologies after its opening up to trade with England. A separate issue, not addressed in this paper, is why China did not develop its own labor-saving technologies earlier.

We note that all parameters except for the iceberg costs are kept at the values calibrated to the English experience. An obvious question is whether it is appropriate to use the benchmark values for the purpose of looking at China. One difference between England and China in the seventeenth century is the urbanization rate. According to Table 2, the English urbanization rate in 1600 was 7.5%. For China in 1700, the urbanization rate was roughly half this number, 4%. Solving the model with $\mu = 0.96$ is of course possible, but it would imply a skill premium of more

[27] In a sense, this time period should be seen as a lower bound since the calibration does not entertain differences in public safety nets between England and China.

than 3, well above estimates for China in this era. Based on data from 1769, Van Zanden (2009) estimates the skill premium in China to be somewhere between 1.25 and 1.85, roughly the same as in England. Thus, to calibrate to $\mu = 0.96$, it would be necessary to adjust α for China as well. When this is done, the results are essentially the same as using the English values for both μ and α.

6 Concluding Remarks

In this paper we have argued that spatial competition may be a key determinant of long-run development. The novel mechanism we have proposed is based on the interaction between the spatial distribution of cities and the endogenous rise and decline of technology-blocking institutions. Because these institutions — which we refer to as guilds — are organized at the level of cities, their monopoly power is limited by the competition from neighboring cities. With strong enough inter-city competition, profits from introducing labor-saving technology are sufficient to compensate guild members for the negative effects of innovation, and their resistance breaks down.

Our theory contributes to a better understanding of the *Industrial Revolution* and the *Great Divergence*. England experienced a large increase in spatial competition in the seventeenth and eighteenth centuries. In a calibrated version of our model, this increase in inter-city competition is able to predict the timing of England's take-off. Historical and empirical evidence further support the hypothesis that spatial competition critically affected the profitability for firms to adopt new technologies and the incentives for guilds to block those innovations. When comparing China to England, our model correctly predicts the later development of China. Although China's cities were larger than England's, they were geographically much farther apart. The lower intensity of spatial competition in China meant that industries in a particular city could not easily steal business from those same industries in neighboring cities, making it less likely for guilds to give up resistance.

We believe that the mechanism described in this paper can be used to gain insight on a number of issues. One such area relates to the argument that political fragmentation contributed to Europe's earlier take-off. One interpretation is that inter-state competition for resources spurred military innovation that spilled over into civil society (Jones, 1981; Lagerlöf, 2014). Extending our model to the national level would provide an alternative interpretation, based on the relation between spatial competition and innovation. This would be consistent with Mokyr (2007) who describes how political fragmentation led to greater inter-city competition for talent in Europe.

Another area that deserves further attention relates to the geographic extension of technology-blocking institutions. Whereas craft guilds were typically organized at the level of industries and cities, in a world with greater inter-city competition we would expect guilds to expand their reach to control multiple cities. In fact, as the *Industrial Revolution* unfolded, we saw the emergence of social movements, such as trade unions, organized at the national, and sometimes even at the international, level.

References

[1] Aghion, P., Bloom, N., Blundell, R., Griffith, R. and Howitt, P., 2005. "Competition and Innovation: an Inverted-U Relationship," *Quarterly Journal of Economics*, 120, 701-728.

[2] Bairoch, P., Batou, J., and Chèvre, P., 1988. *La population des villes européennes de 800 à 1850.* Centre d'Histoire Economique Internationale de l'Université de Genève, Librairie Droz.

[3] Binfield, K., 2004. *Writings of the Luddites,* Baltimore: Johns Hopkins University Press.

[4] Bradstock, T. R., 1984. *Craft Guilds in Ch'ing Dynasty China,* Unpublished PhD Dissertation, Harvard University.

[5] Britnell, R. 2008 [2000]. "The Economy of British Towns 1300-1540," in: Palliser, D.M. (ed.), *The Cambridge Urban History of Britain*, Vol. 1, Chapter 14, Cambridge: Cambridge University Press.

[6] Broadberry, S. and Gupta, B., 2006. "The Early Modern Great Divergence: Wages, Prices and Economic Development in Europe and Asia, 1500-1800," *Economic History Review*, 59, 2-31.

[7] Cao, S., 2000. *Zhongguo renkoushi: Qing shiqi (Population history of China: Qing period)*, Shanghai: Fudan University Press.

[8] Clark, G., 2001. "The Secret History of the Industrial Revolution," UC Davis, unpublished working paper.

[9] Clark, G. 2007. *A Farewell to Alms: A Brief Economic History of the World.* Princeton: Princeton University Press.

[10] Daumal, M. and Zignago, S., 2010. "Measure and Determinants of Border Effects of Brazilian States," *Papers in Regional Science,* 89, 735-758.

[11] De Munck, B., Lourens, P. and Lucassen, J., 2006. "The Establishment and Distribution of Craft Guilds in the Low Countries, 1000-1800," in: Prak, M., Lis, C., Lucassen, J. and Soly, H. (eds.), *Craft Guilds in the Early Modern Low Countries*, Aldershot: Ashgate.

[12] Desmet, K. and Parente, S.L., 2014. "Resistance to Technology Adoption: The Rise and Decline of Guilds," *Review of Economic Dynamics*, 17, 437-458.

[13] Desmet, K. and Parente, S.L., 2012. "The Evolution of Markets and the Revolution of Industry: A Unified Theory of Growth," *Journal of Economic Growth*, 17, 205-234.

[14] Desmet, K. and Parente, S.L., 2010. "Bigger is Better: Market Size, Demand Elasticity and Innovation," *International Economic Review*, 2010, 51, 319-333.

[15] Dinopoulos, E. and Syropoulos, C., 2007. "Rent Protection as a Barrier to Innovation and Growth," *Economic Theory* 32, 309-332.

[16] Disdier, A.-C. and Head, K., 2008. "The Puzzling Persistence of the Distance Effect on Bilateral Trade," *Review of Economics and Statistics*, 90, 37-48.

[17] Eden, F. M., Sir, 1797. *The State of The Poor; Or, An History of The Labouring Classes In England, From The Conquest To The Present Period,* Vols. i-iii, London: J. Davis.

[18] Eggimann, G., 1999. *La population des villes du tiers monde, 1500-1950.* Centre d'Histoire Economique Internationale de l'Université de Genève, Librairie Droz.

[19] Epstein, S. R., 2008. "Craft Guilds in the Pre-Modern Economy: A Discussion," *Economic History Review*, 61, 155-74.

[20] Epstein, S.R., 1998. "Craft Guilds, Apprenticeship and Technological Change in Preindustrial Europe," *Journal of Economic History*, 53, 684 713.

[21] Foreign Office (Great Britain), 1875-8. *Commercial Reports from Her Majesty's Consuls in China,* London: Harrison & Sons.

[22] Gadd, I.A. and Wallis, P., 2002. *Guilds, Society & Economy in London 1450-1800*, London: Centre for Metropolitan History.

[23] Galdón-Sánchez, J.E. and Schmitz, J.A., Jr. 2002. "Competitive Pressure and Labor Productivity: World Iron-Ore Markets in the 1980s," *American Economic Review*, 92, 1222-35.

[24] Galor, O. and Moav, O., 2002. "Natural Selection and the Origin of Economic Growth," *Quarterly Journal of Economics*, 117, 1133-1192

[25] Gelderblom, O. and Grafe, R., 2010. "The Rise and Fall of the Merchant Guilds: Re-thinking the Comparative Study of Commercial Institutions in Premodern Europe," *Journal of Interdisciplinary History*, 40, 477-511.

[26] Greif, A., 2006. "Family Structure and European Institutional Exceptionalism: the Origin of Corporations," *American Economic Review Papers & Proceedings*, 96, 308-312.

[27] Greif, A. and Iyigun, M., 2013. "Social Organizations, Violence, and Modern Growth," *American Economic Review Papers & Proceedings*, 103, 534 38.

[28] Greif, A., Iyigun, M. and Sasson, D., 2012. "Social Organizations, Risk Sharing Institutions and Economic Development," in: Aoki, M. (ed.), *Proceedings of the 16th World Congress of the International Economic Association.*

[29] Gross, C., 1890. *The Gild Merchant*, Oxford: Clarendon Press.

[30] 't Hart, M.C., 1993. "Freedom and Restrictions: State and Economy in the Dutch Republic, 1570-1670," in: Davids, K. and Noordegraaf, L. (eds.), *The Dutch Economy in the Golden Age*, Amsterdam: Nederlands Economisch-Historisch Archief.

[31] Helpman, E. and Krugman, P. R., 1985. *Market Structure and Foreign Trade*, Cambridge: MIT Press.

[32] Hibbert, F.A., 1891. *The Influence and Development of English Gilds,* New York: Sentry Press.

[33] Hickson, C. R. and Thompson, E.A., 1991. "A New Theory of Guilds and European Economic Development," *Explorations in Economic History*, 28, 127-68.

[34] Holmes, T.J. and Schmitz, J.A., 1994. "Resistance to Technology and Trade between Areas," Research Department Staff Report 184, Federal Reserve Bank of Minneapolis.

[35] Hudson, P., 1986. *The Genesis of Industrial Capital,* Cambridge, New York City and Melbourne: Cambridge University Press.

[36] Hummels, D. and Lugovskyy, V., 2009. "International Pricing in a Generalized Model of Ideal Variety," *Journal of Money, Credit and Banking*, 41, 3-33.

[37] Jacks, D.S., Meissner, C.M., and Novy, D., 2011. "Trade Booms, Trade Busts, and Trade Costs," *Journal of International Economics*, 83, 185-201.

[38] Jernigan, T. R., 1904. *China's Business Methods and Policy,* London: T. F. Unwin.

[39] Jones, E. L., 1981. *The European Miracle*, Cambridge: Cambridge University Press.

[40] King, S., 2000. *Poverty and Welfare in England 1700-1850,* Manchester University Press.

[41] Krusell, P. and Rios-Rull, J.V., 1996. "Vested Interests in a Positive Theory of Stagnation and Growth," *Review of Economic Studies*, 63, 301-329.

[42] Lagerlöf, N.-P., 2014. "Population, Technology and Fragmentation: the European Miracle Revisited," *Journal of Development Economics* 108, 87-105

[43] Ma, D., 2005. "Between Cottage and Factory: the Evolution of Chinese and Japanese Silk-Reeling Industries in the Latter Half of 19th Century," *Asia Pacific Economy*, 10, 195-213.

[44] MacGowan, J., 1886. "Chinese Guilds or Chambers of Commerce and Trade Unions," *Journal of the China Branch of the Royal Asiatic Society for the Year 1886*, XXI, new series, no. 1, 2, Article VIII, 133-92.

[45] MacLeod, C., 1998. *Inventing the Industrial Revolution: The English Patent System, 1660-1800,* Cambridge: Cambridge University Press.

[46] Maddison, A., 2001. *The World Economy: A Millennium Perspective,* Paris: Development Centre of the OECD.

[47] Masschaele, J., 1993. "Transport Costs in Medieval England," *Economic History Review*, 46, 266-279.

[48] Mokyr, J., 2007. "The Market for Ideas and the Origins of Economic Growth in Eighteenth Century Europe," *Tijdschrift voor Sociale en Economische Geschiedenis*, 4, 3-38.

[49] Mokyr, J., 1998. "Invention and Rebellion: Why Do Innovations Occur At All? An Evolutionary Approach," Northwestern University.

[50] Mokyr, J., 1997. "The Political Economy of Technological Change: Resistance and Innovation in Economic History," Northwestern University.

[51] Mokyr, J., 1992. "Technological Inertia in Economic History," *Journal of Economic History*, 52, 325-338.

[52] Mokyr, J., 1990. *The Lever of Riches. Technological Creativity and Economic Progress.* New York: Oxford University Press.

[53] Moll-Murata, C., 2008. "Chinese Guilds from the Seventeenth to the Twentieth Centuries: An Overview," *International Review of Social History*, Supplement, 213-247.

[54] Morison, E.E. 1966. *Men, Machines, Modern Times,* Cambridge, Mass.: Cambridge University Press.

[55] Morse, H.B., 1909. *The Gilds of China,* London: Longmans, Green and Co.

[56] Munro, J. H., 1997. "The Origin of the English 'New Draperies': The Resurrection of an Old Flemish Industry, 1270-1570," in: Harte, N.B. (ed.), *The New Draperies in the Low Countries and England, 1300-1800,* Oxford: Oxford University Press.

[57] Nickell, S. J., 1996. "Competition and Corporate Performance," *Journal of Political Economy*, 104, 724-46.

[58] North, D.C., 1981. *Structure and Change in Economic History*, New York: Norton.

[59] Ogilvie, S., 2008. "Rehabilitating the Guilds: A Reply," *Economic History Review*, 61(1), 175–182.

[60] Parente, S.L. and Prescott, E.C., 1999. "Monopoly Rights: A Barrier to Riches," *American Economic Review*, 89, 1216-1233.

[61] Pirenne, H., 1936. *Economic and Social History of Medieval Europe,* New York: Harcourt Brace & World.

[62] Pomeranz, K., 2000. *The Great Divergence: China, Europe, and the Making of the Modern World Economy*, Princeton, NJ: Princeton University Press.

[63] Randall, A., 1991. *Before the Luddites: Custom, Community, and Machinery in the English Woolen Industry, 1776-1809,* Cambridge University Press, Cambridge.

[64] Richardson, G., 2004. "Guilds, Laws, and Markets for Manufactured Merchandise in Late-medieval England," *Explorations in Economic History*, 41, 1-25.

[65] Rosenthal, J.-L. and Wong, B.R., 2011. *Before and Beyond Divergence*, Cambridge, Mass.: Harvard University Press.

[66] Royal Society of Arts (Great Britain), 1784-1845. *Transactions of the Society Instituted at London for the Encouragement of Arts, Manufactures, and Commerce*, London.

[67] Rozman, G., 1973. *Urban Networks in Ch'ing China and Tokugawa Japan,* Princeton, NJ: Princeton University Press.

[68] Schmitz, J.A., 2005. "What Determines Productivity? Lessons from the Dramatic Recovery of the US and Canadian Iron Ore Industries Following their Early 1980s Crisis," *Journal of Political Economy*, 115, 582-625.

[69] Seligman, E.R.A., 1887. "Two Chapters on the Mediaeval Guilds of England," *Publications of the American Economic Association*, 2, 9-113.

[70] Shiue, C.H. and Keller, W., 2007. "Markets in China and Europe on the Eve of the Industrial Revolution," *American Economic Review*, 97, 1189-1216.

[71] Slack, P., 1999. *From Reformation To Improvement: Public Welfare in Early Modern England,* Oxford: Oxford University Press.

[72] Smith, A., 1774. *An Inquiry into the Nature and Causes of the Wealth of Nations [1774]*, edited by E. Cannan. Chicago University Press, Chicago, 1974.

[73] Solar, P.M., 1995. "Poor Relief and English Economic Development Before The Industrial Revolution," *Economic History Review*, New Series, 48, 1-22.

[74] Szostak, R., 1991. *The Role of Transportation in the Industrial Revolution*, Buffalo, NY: McGill-Queens University Press.

[75] Van Zanden, J.L., 2009. "The Skill Premium and the 'Great Divergence'," *European Review of Economic History*, 13, 121-153.

[76] Voigtländer, N. and Voth, H.-J., 2006. "Why England? Demographic Factors, Structural Change and Physical Capital Accumulation during the Industrial Revolution," *Journal of Economic Growth*, 11, 319-61.

[77] Will, P.-É. and Wong, B.R., 1991. *Nourish the People. The State Civilian Granary System in China*, with Lee, J., Center of Chines Studies: University of Michigan.

[78] Willan, T. S., 1976. *The Inland Trade: Studies in English Internal Trade in the Sixteenth and Seventeenth Centuries*, Manchester: Manchester University Press.

[79] Wong, R.B., 1997. *China Transformed: Historical Change and the Limits of European Experience*, Ithaca, NY: Cornell University Press.

[80] Yue, Z., Skinner, G.W., and Henderson, M., 2007. *ChinaW Dataset*, Davis: University of California, Regional Systems Analysis Project.