# Risk Sharing and the Industrial Revolution: A Macroeconomic Approach

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**Abstract**

This paper analyzes the role of equilibrium, risk-sharing institutions in leading to the structural transformation in the production technology that brought about the industrial revolution. Guided by history, the model considers two risk-sharing institutions each of complements an existing social structure. The first is a 'Chinese' style, lineage-based institution: members choose technology based on capital-weighted majority rule and share the output. The second is a 'British' style, institution complementing its individualistic social structure: a state-based wealth redistribution institution. Under the lineage-based institution risk-sharing within lineages fosters the adoption of high-risk, high-return technology. Yet, it reduces this adoption by giving the elders, who are capital-rich but more risk-averse, more say in technology choice. The paper examines analytically the factors influencing which structure better promotes adoption of high-risk, high return technology that fosters industrialization. This highlights the possible importance of state-based insurance – the British Poor Law of 1601 – in tilting the balance in favor of the English system and hastening the Industrial Revolution in Britain. Simulation reinforces the relevance of our results.

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*"...Modern theories of economic growth have failed to deal adequately with the change in human condition that the industrial revolution represents. These theories are built around a positive rate of technological change, either simply assumed or generated as an equilibrium outcome by the assumption of constant or increasing returns to the accumulation of knowledge...We need to discover a more general theory of which the two we now have can be seen as special cases, a theory that lets us see the nature of the transition from the situation of stable incomes that has characterized most of history to the sustained growth that has emerged in the last two centuries..." Lucas, R. (2002), "The Industrial Revolution: Past and Future", Lectures of Economic Growth.*

# 1 Introduction

The Industrial Revolution marks the transition to modern economic growth. The determinants of its causes, timing and location are therefore a central question in economics. Economic historians are divided on whether the Industrial Revolution reflects particularly English features or whether it transpired there accidently. Proponents of the English particularity view emphasized its unique growth-enhancing features, such as limited government, higher per-capital income, a lower population growth rate, better patent protection, a machine tool industry and labor market institutions (e.g., North and Weingast 1989; Mokyr 1977, 1992, 1999, 2007; Solar 1999; Voigtländer and Voth 2006). Proponents of the accidental view countered that these distinctions were not particularly significant on the eve of the Industrial Revolution, that industrialization was a slow process that was followed after a short leg by other European states (e.g, Craft 1977; Pomeranz 2000; Clark 2007).

Growth theory has predominantly adopted the accidental view of industrialization. It examines mainly three long-run historical processes that render industrialization – a shift from a diminishing returns-to-scale technology to a more efficient, constant-return-to-scale technology – inevitable. The first process is a gradual technological progress (e.g., Hansen and Prescott 2002; Gollin, Parente and Rogerson 2002). The second process is that of population growth which increases the rate of human capital accumulation (e.g., Kremer 1990; Jones 1999). The third process is one of random mutations in preferences or fertility rate that increases productivity (e.g., Galor and Weil

1996, 2000; Galor and Moav 2002).

These analyses ingeniously explain many stylized facts associated with industrialization, such as an increase in per-capita consumption and the demographic transition. Yet, as noted by Lucas (2002), they assumed exogenous processes of productivity growth and in this sense they fail to explain industrialization. Hansen and Prescott (2002), for example, assumed that total factor productivity increases over time to the point at which adopting industrial technology is profitable. Kremer (1990) assumed that productivity grows as the population increases because each person has some probability of being 'inventive' and ideas are public goods. Galor and Weil (1999) assumed that the rate of technological progress is a function of education and population size.

Why, then, was England the first country to industrialize? Why were only a few countries, particularly Western ones, quick to imitate it? In the accident view of industrialization, these outcomes were due to exogenous shifts in functional forms or some parameters. "The [English] Industrial Revolution transpired due to an exogenous increase in research productivity" (Kremer 1990, p. 706). "The process of industrialization seems to involve a dramatic increase in the return to human capital" (Lucas 2002, p. 5). Others focused on distinctions in endogenous variables (e.g., fertility, income) prior to the Industrial Revolution and evaluated their impact on industrialization. (Voigtländer and Voth, 2006)[1]. While insightful, this does not explain why these variables differed to begin with.

The main contribution of this paper is to endogenize productivity growth as a function of risk-sharing institutions. Risk-averse economic agents choose among technologies that differ in their risk characteristics. Technology therefore depends on the available (equilibrium) risk-sharing institutions. This approach, and the modeling of the risk-sharing institutions, corresponds to the observed differences between more individualistic states (e.g., England) that industrialized earlier, and more collectivist societies (e.g., China) that did so later. The analysis indicates that risk-sharing institutions might have played a role in these distinct growth trajectories.

In China, relief for the poor was provided by kinship groups dominated by the elders. (For ease of exposition, we refer to such groups as 'lineage'[2].) In England, however, relief was provided by the state following the Old Poor

[1]This illuminating paper finds that the Old Poor Law did not substantially influence England's industrialization by enhancing labor market participation by the poor.

[2]Fearing unrest, the Empire kept well stocked granaries for relief when natural disas-

Law (1601).While the paper presents the historical processes that led to this institutional distinction, in our model each of them is an equilibrium outcome. Our analysis examines the impact of these distinct risk-sharing institutions on industrialization. As is common in the Unified Growth Theory, we assume that there are two technologies that affect capital productivity. One is characterized by low risk and low returns, and the other by high-risk and high returns. Agents' risk-aversion decrease in their wealth but increases in their age[3]. Young agents are endowed with labor and more elderly agents with capital. Production requires both capital and labor.

We model the lineage-based ('Chinese') risk-sharing institutions as follows. Lineage members jointly choose a technology, the weight of a member's choice increases in her capital (implying that the elders dominate), and output is shared among members. Under the state-provided ('English') risk-sharing institution, a young agent rents capital from an older one and chooses a technology. The introduction of a Poor Law that provided better insurance constitutes a shift in the distribution of the technological shocks that an agent faces. (The law can be financed by ex post transfers.)

Because the model is comparable to existing ones, it yields the common insights that there are some parameters set under which industrialization – the adoption of risky technology – can eventually transpire irrespective of the risk-sharing institution. The new elements in our model, however, also provide additional insights. The rate of the adoption of the riskier technology is delayed due to different factors in each economy. It is delayed due to incomplet capital market under the state-provided institution but it is delay due to the elders' higher risk aversion under the lineage-based institution. This difference has significant growth implications. If the elderly agents are sufficiently risk averse, riskier technologies will be adopted under the state-based risk-sharing institution but not under the lineage-based institution. Furthermore, it is possible that under a lineage-based institution industri-

ters struck. For simplicity's sake we use the term lineage loosely to describe organized patrilineal descent groups. For distinctions among these and related terms developed in anthropology, see Ebrey and Watson, 1986, pp. 4-6.

[3]Contemporary empirical analyses found that the elders are more risk averse. E.g., Einav and Cohen (2007) found that risk aversion declines after the age of 18 and increases after the age of 48. See also Agarwall, Sumit, John C. Driscoll, Gabaix, and Laibson 2006; Halek and Eisenhauer, 2001; Riley and Chow, 1992. Early twenty century Chinese peasants decisions regarding crops and labor were influenced by risk aversion (Wiens 1976) while in the modern economy low risk aversion fosters entrepreneurship (van Praag and Cramer, 2001).

alization would never transpire but would have if a state-based institution had prevailed. Societies that are identical in terms of technology, preferences, and endowments but in which different self-enforcing risk-sharing institutions prevail, can exhibit very different growth trajectories. In one an industrial revolution can transpire but in the other it cannot. Finally, a shift in the risk distribution – a Poor Law – that reduces an individual's risk under the state-based institution, hastens industrialization.

The possible impacts of distinct institutions on growth trajectories has been recognized in the literature although institutions were not integrated in the analysis. Hansen and Prescott (2002), for example, noted that "we have not explored how policy and institutions, by discouraging or preventing the invention and adoption of new ideas, might play an important role in determining when" industrialization transpires and "the fact that the industrial revolution happened first in England, ... rather than ... China ... is perhaps due to the institutions and policies in place in these two countries" (p. 1215; also Jones 1999 and Galor 2005). Our analysis identifies these institutions and analytically demonstrates that they indeed might matter.

In addition, however, our analysis highlights that distinct growth trajectories might reflect more than different functional forms or the value of a particular parameters. Current models capture various (equilibrium) features of the Europan societal organization such as nuclear families and individualistic decision-making. These features, as revealed by history and is captured in our model, have not universally prevailed. England and China differed in who made economic decisions, not necessarily in agents' time discounts. Distinct equilibrium societal organizations – rather than the value of a particular functional form or parameters – may be at the core of growth trajectories and these features' persistence might be the reason for divergence in growth rates.

To further evaluate the plausibility of this argument we simulate the model mimicking the historically observed industrialization of England and its absence in China. The 1601 Poor Law could have sufficiently reduced risk, leading the economic agents to choose riskier, Pareto- superior technologies that hastened industrialization.

While an empirical evaluation of our analysis is beyond the scope of this paper, it provides a rational and consistent account for several empirical observations. First, the growth in real wages (relative to population growth) did not begin in England after 1750 following the great technological inventions, but rather in the first half of the 17th century (Clark 2005). The rise in productivity growth during the 17th century is consistent with the assertion that the Poor Law of 1601 mattered. Second, England was not particularly inventive during its Industrial Revolution. Its growth reflects its innovative ability – to adopt and commercialize – inventions made elsewhere (Mokyr 1990)[4]. This is a prediction of our analysis that focuses on the incentives to innovate provided by risk-sharing institutions Third, continental Europe was relatively more individualistic and had state-based risk-sharing institutions similar, although initially inferior, to England's. As our analysis predicts, Europe industrialized relatively quickly after England although China did not.

Last and not least, our analysis is consistent with a longer view of the technological histories of Europe and China . At some point, China was the world's technological leader. It "developed an amazing technological momentum, and moved, as far as these matters can be measured, at a rate as fast as or faster than Europe" (Mokyr 1990, p. 208) particularly during the Song dynasty (960-1279). Yet, shortly after the fall of the Song Ming dynasty, technological development slowed and China became, relatively speaking, technologically stagnant. (Ibid. 219).

Our analysis predicts that the rate of technological progress will be higher in China when the elders had less authority. Indeed, under the Song, killing a son was a crime (although killing an unfilial son entailed less punishment). As severe this law may seem, it became even harsher. After the Song it was not even a crime for a father to kill an unfilial son! (Hamilton 1990, p. 86.) Clearly, disobeying one's father in post-Song China was a dangerous proposition. Similarly, if our argument holds, we would expect that the Song provided better state-based, risk-sharing institutions than did other dynasties. Indeed, Wang Anshi, a prominent minister during that time, asserted that the state was responsible for providing its citizens with a decent living. Under his direction the state instituted pensions for the needy. (Ebrey, Walthall, and Palais, 2005). Later dynasties, in contrast, did not follow this example.

An extensive economic literature examines various risk-sharing institutions. For example, Lee and Higgs (1982), Ackerberg and Botticcini (2000, 2002), Hoffmann (1982, 1984), McCloskey (1972, 1976) and Stiglitz (1974) have focused on sharecropping. Fishback and Kantor (1996) and Moriguchi

[4] France, in which inventors were rewarded by the Crown was an important source of inventions. For an economic analysis of the French system, see Kremer (1998).

(2003) have examined workers' insurance. De Lara (2004) examined the maritime insurance contracts. Kocherlakota (1996) and Ligon, Thomas and Morral (2000) have provided some general theoretical framework for failures in perfect risk sharing. We focus on the inability to insure agents who adopted high-risk technologies. Our analysis abstracts from fertility issues and hence it is not suitable to match the stylized facts of consumption and fertility in the typical Malthusian framework. Despite fertility being extremely important, we merely focus on the effects of risk sharing in the adoption of risky technologies. There could be, however, potential linkages between fertility and risk sharing. Large families could act as insurance devices, for instance. We leave this issue for future work.

Section 2 provides historical background on risk-sharing institutions and elders' authority in England and China. Section 3 describes the model. Section 4 provides the numerical results of our model and Section 5 concludes.

# 2 Historical Background: Poor Law

Three observations underpin the assumptions we make in modeling risk-sharing institutions in England and China. First, the incompleteness of pre-modern capital markets implied that one could not insure himself against idiosyncratic risks. Second, lineages dominated pre-modern China but not England. Third, state-based, risk-sharing institutions were more effective in England than in China after 1601 while kin-based, risk-sharing institutions were more effective in China. In addition, in China elders were better able to influence their children's economic choices.

## 2.1 Capital market incompleteness

We are not familiar with any pre-modern economy in which idiosyncratic individual-level risks were insured to a significant degree through the capital markets. The historical records indicate that the benefit from diversifying risk has been known at least since the 3rd millennium BC when Chinese merchants sent their wares abroad in multiple ships. The earliest known insurance policies, however, are from 14th century AD. Genoa in which they were used to insure ships and and shipments against 'acts of God.' Fire insurance was first introduced in England after the Great Fire of London (1666). Life and health insurance were not introduced until the 19th century following the development of greater statistical knowledge. This history is not surprising given the moral hazard and adverse selection problems associated with insurance against idiosyncratic, individual-level risks.

Evidence indicates that in pre-modern economies, these risks were not insured through the capital market. The analysis of the English open field system is the best known example of failure of this capital market (McCloskey 1972, 1975; Fenoaltea 1976). To insure against a bad harvest, English peasants geographically diversified their land holdings despite the fact that this reduced their expected yield by 7 percent. Less known, but equally revealing, is that the expected market return from innovative activities in the pre-modern world was negative (Nye 1991). Gutenberg, for example, invented the printing press, yet died in poverty in 1468.

## 2.2 Distinct social structures

In the centuries prior to the industrial revolution, social structures in England and China evolved in opposite directions. England, generally similar to Europe, moved away from large, kin-based structures such as lineages and tribes, while in China lineages gained dominance as economic and social units.

From the fourth century, the Church in Europe advanced a dogma whose implications dissolved kin-based social structures. It discouraged practices that enlarged the family, such as adoption, polygamy, concubinage, divorce, and remarriage. The Church also restricted marriages among kin (consanguineous marriages) often up to the seventh degree[5]. Kin marriages, particularly among cousins, have historically provided an important means of maintaining kinship groups. The ability of parents to retain kinship ties through arranged marriages was also restricted by prohibiting unions without the bride's explicit consent. (Goody 1983; Greif 2006, 2007.)

Eliminating kin-based social structures arguably served the interests of the Church in its attempt to create a Christian society in which it was dominant. Although European family structures did not evolve monotonically toward the nuclear family, nor was their evolution geographically and socially uniform, by the late medieval period the nuclear family was dominant

[5] In the late Roman period, the law prohibited marriage among relatives to the 3rd degree, implying that first cousins could marry. The Roman law also required consent to these marriages. Herlihy (1985), pp. 7-8.

in Western Europe and became the norm. (Mitterauer et. al. 1982; Goody 1983; Ekelund et. al. 1996;Herlihy, 1985; Greif 2006, chapter 8).

Evidence from various sources supports this claim. For example, the (Germanic) Salic law of the sixth century denied legal rights to anyone not affiliated with a large kinship group. But by the eighth century the term family among the Germanic tribes already denoted one's immediate family. Tribes and lineages, by and large, were no longer institutionally relevant. (Guichard and Cuvillier 1996.) By the 10th century, the English King Edward issued a law mandating that every male join a group that would guarantee his appearance in court, implying that kinship groups could no longer be held accountable as was the case when the Salic law was specified.

In later centuries there is quantitative evidence of the decline of large kinship groups. English court rolls from the thirteenth century reflect that cousins were not more likely than non-kin to be in each other's presence (Razi 1993). The English poll-tax records of 1377 indicate that there were approximately 2.3 individuals over the age of thirteen per-household (Schofield 2003, p. 83). This was also the mean household size of those receiving poor relief in Strasbourg in 1523 (Jutte 1996, p. 382). Large kinship groups remained important only among nobility and on the fringes of Europe, such as in Scotland.

In contrast to Europe, kinship groups prevailed in China to the twentieth century[6]. They were not a marginal feature in Chinese society but were culturally, socially, politically and economically prominent. Indeed, historians have identified the ideology and practice of patrilineal descent as the backbone of Chinese society (e.g., Freedman 1958). Filial pity and ancestor worship were central to the culture. Social relations were often kinship-based as were economic organizations (e.g., Hamilton 1990). Lineages provided members with protection, connections and public goods in an empire whose magistrates were positioned above the county level. The state, in turn, used kin-based organizations for tax collection and considered male descendants of a household a jointly liable tax unit. This created further shared interests among kin.

More specifically, during the Tang (618 690, 705 907) and the Song (960 1279) dynasties most historical references to kinship groups are to "communal families." These were domestic units that had not divided – in terms of

[6] The discussion particularly draws on Smith 1987; Ebrey and Watson 1986; Szonyi 2002; Freedman 1958; Watson 1982; Liu 1959.

property or members – for five, six, or even ten generations. The state praised communal families as an ideal form of organization and supported exceptional ones through tax exemptions. Communal families are also often reflected in the historical records of later dynasties. It is difficult to quantitatively evaluate how many communal families existed although the existence of some is beyond doubt. However, given the complexity of supporting, organizing and maintaining the coherence of such groups in one location, large communal families must have been relatively rare.

The nuclear (conjugal) family, the extended family and various lineage organizations were the common kin groups in late Imperial China. During that period, most Chinese households consisted only of a nuclear family, a couple and their unmarried children. Larger households, however, were culturally esteemed and beneficial practically because they consolidated assets and local political power under family control. Hence, many of those with sufficient means maintained larger households: a 'stem' family, that also included at least parents and a married son and his family. The extended family was an augmented version of the stem family, encompassing members of several families related through the male line. Members often lived in a particular compound, had common property and an internal dispute-resolution mechanism.

Lineages were looser associations of relatively large numbers of kin and "were the predominant form of kinship organizations in late imperial China" (Ebrey and Watson, 1986, pp. 1, 6; Watson 1982). Detailed statistics on the share of the population with lineage affiliation is unknown to us. Lineages, however, dominated the south of China, were less common at the center and least common in the north of China. Lineage estates were used to promote their members common interests without having to strictly regulate their members, as was required in communal or extended families. In many other respects, however, lineages were the functional successors of communal families. They similarly exerted considerable control over individuals, regulated their access to material benefits, and acted as social and political units.

## 2.3 Risk-sharing and Parental Authority

Pre-modern rulers recognized that alleviating poverty is important in keeping social order and their control. Poverty had been alleviated, however, in a manner complementary to the way the state was organized. Indeed, the absence of large kinship groups in England and their prevalence in China influenced the development of risk-sharing institutions in both countries. From the early 17th century, parishes in England were legally obligated to provide for the poor while in China, provision fell to extended families and lineages.

More specifically, prior to the 16th century, Europeans relied on various non-state risk-sharing institutions. In particular, secular and religious corporations – monasteries, fraternities, mutual-insurance guilds, and communes – assisted the poor or their members in times of need. They provided individuals with such services as poor relief and unemployment, disability and life insurance. The extent of coverage was wide-spread. The total capacity of England's monasteries for grain storage, which provided famine and poor relief, was more than was required to sustain the Kingdom's population for longer than a year (Fenoaltea 1976)[7]. In the early 16th century, the majority of England's rural and urban population belonged to corporations – fraternities and guilds – that provided social safety nets (Richardson 2005). The same pattern seems to have prevailed elsewhere in Europe (Reynolds 1984; Brenner 1987).

Many of the corporations through which insurance was provided, were associated with the Catholic Church. Hence, Protestant rulers dismantled them during the 16th century Reformation. In the religious wars of the Counter-reformation, Catholic rulers also confiscated the properties of these corporations to finance their armies. In the long run, the lack of welfare provision threatened social order and states responded by providing poor relief. Local administrative bodies within the European states, such as parishes and cities, were required by law to provide social safety nets.

In England, Henry VIII established the Anglican Church and dismantled all monasteries and mutual-assistance corporations in 1538. The Poor Law Act of 1601 formalized the emerging alternative. Local parishes were authorized to levy a property tax and were obliged by law to care for the poor. Similar systems were established elsewhere in Europe around that time. (Geremek 1997; Jutte 1996; de Vries and de Woude 1997, pp. 654-664). Commonly, local authorities in these systems provided poor relief. Making local authorities responsible probably reflects the limited administrative capacities of the pre-modern European state and the need to mitigate moral hazard and adverse selection problems. Local administrators – who often paid the taxes to feed the poor – had the information and incentive to monitor the poor and support only the 'deserving' ones. (Tim??).

[7] Customary poor relief was also practiced on the village level.

While provision of poor relief by the state was a European phenomenon from the 17th century, not all states were equally effective providers. (Boyer 1990; Lindert ??; Solar 1999.) The English Poor Law system was more reliable and more generous. In England, expenses were financed through a variable poor rate on the assessed rental value of local property. Continental poor relief, by contrast, was financed from a variety of sources: voluntary donations, capital income, subsidies from local and national governments, and general tax revenues. Funding was therefore less reliable. Furthermore, in England the right to relief was well defined in the law while on the continent rights were vaguely defined, less credibly assured, and the granting of relief was, in general, at the discretion of local authorities. Annual spending on poor relief in England amounted to about 1 percent of the national income in the seventeenth century and rose to about 2.5 percent at its peak, providing some support to about 11 percent of the population. Expenditure per-capita was 7.5 times higher than in France in 1780s, 2.5 times higher than in the Netherlands in 1820s, and 5 times higher than in Belgium in 1820s.

There were many changes and greater diversity of poor relief institutions in Imperial China[8]. Until the modern period, however, the state only sporadically financed monetary and/or medical aid to the poor, sick, and disabled. Buddhist monasteries and temples provided some medical service, fed the hungry and sheltered the aged and decrepit. Their support, however, was uncertain as they fed any poor, including those who were 'undeserving.' Benevolent societies were established after 1580, particularly by members of the mercantile elite and the gentry. Yet, their forms and functions were often rigid and did not adjust to various needs.

Kinship groups were the major source of aid to the poor and the aged. Their role in providing risk-sharing is most notable in the organization of communal and extended families. Some communal families included hundreds and even thousands of members. In such families, all property was held in common and the "underlying principle was distribution of income to all members equally according to need, just as though they were members of small family" (Ebrey and Watson 1986, p. 33). In particular, the younger members of the lineage worked, while the elders made the communal decisions. Communal families were promoted by the state and the educated elite

[8]The discussion particularly draws on Smith 1987; Ebrey and Watson 1986; Szonyi 2002; Freedman 1958. We are not familiar with quantitative analysis of these kinship organizations' relative importance.

as the ideal goal for every family. We do not have data about their prevalence in reality, but the difficulties of maintaining a communal family of large size are transparent.

Indeed, as the population grew, lineages became the dominant kinship organization. Although intra-lineage charity was common, they were less egalitarian than communal and extended families. Estates were prone to capture by sub-set families of a lineage. Yet, they seem to have been the most common and reliable source of poor relief, particularly after Fan Chung-yen (989-1052) created the first charitable estate. A lineage established a charitable estate and used its income for lineage rituals and to provide it members with education, income, and support for weddings, burials and illness. Members in poverty received more benefits and sometimes free lodging. The state motivated the lineage to care for its poor by considering it legally responsible for crimes committed by its members. Lineages assumed quasi governmental functions such as those involved with social welfare and primary education.

China's provision of risk-sharing institutions and the alternatives, which were mainly kinship-based, became less reliable over time. Equally important to our analysis is that within families, the elders controlled property and made decisions even for their adult children. Indeed, in Imperial China, as summarized by Chen (1999, pp. 250-1), "the father had paternal authority over his children, while the children had the duty to practice filial behavior and to support their parents in old age." "The family head had absolute authority and discretion. This kind of power was not only confirmed by the rule of propriety (li) ... but was also protected by state and customary law. These rules provided him with arbitrary power over family property ... [and] in making decisions concerning all aspects of family matters... all earning of family members had to be handed to him.... Even members who settled somewhere else or were temporarily absent, sent their surplus earnings to him." The preferences of the elders dictated the economic actions of young adults. In sharp contrast, long before the 17th century under English law and customs, adult sons were not under the authority of fathers.

# 3 Model

## 3.1 Production Technologies

There is a continuum of populations in $[0,1]$. Each of them has a continnum of agents in $\left[0, \frac{1}{1-\lambda}\right]$. Each agent has a an exogenous death probability $\lambda$ which is unconditional on the agent's age. Agents are young for two periods. Within the young agents there is the newly borns and the young adults. Newly born agents are endowed with one unit of labor and no capital. The rest of the agents have no labor endowment. Labor is supplied inelastically and the utility function is given by:

$$\begin{aligned} U\left(C_\tau^{i,\tau}\right) &= \sum_{t=\{0,1\}} \sum_{s_{\tau+t}\in S} \pi\left(s_{\tau+t} \middle| s_{\tau+t-1}\right) (\beta\lambda)^t u^y\left(c_{\tau+t}^{i,\tau}\left(s_{\tau+t}\right)\right) \\ &+ \sum_{t>1} \sum_{s_{\tau+t}\in S} \pi\left(s_{\tau+t} \middle| s_{\tau+t-1}\right) (\beta\lambda)^t u^o\left(c_{\tau+t}^{i,\tau}\left(s_{\tau+t}\right)\right) \end{aligned}$$

where $u^y$ is the utility function of the agent when young (the first two periods) and $u^o$ the utility function of the agent when old. They are both increasing, concave, continuously differentiable, satisfy the Inada conditions and have decreasing absolute risk aversion (DRRA). Agents are more risk averse when old than when young. $s_{\tau+t}$ is the state of the world at time $\tau + t$, $\pi\left(s_{\tau+t} \middle| s_{\tau+t-1}\right)$ is the conditional markovian probability, $S$ is the space of states of the world, $c_{\tau+t}^{i,\tau}$ is the consumption of agent $i$ of generation $\tau$ in period $\tau + t$ and $C_\tau^{i,\tau} = \left(c_{\tau+t}^{i,\tau}\left(s_{\tau+t}\right)\right)_{t=0}^{\infty}$.

The microfundation of the utility function can be described as follows. Suppose there is a minimum requirement for consumption for all the agents. If all the agents have the same utility function $u$, but the required consumption is higher for the old than for the young due to medical needs, and the DRRA property holds, old agents will be more risk averse. For all possible consumption values, $c$, $u(c - c_o)$ is more risk averse than $u(c - c_y)$ because $c_o > c_y$.

The production function in this economy is given by:

$$Y_t = \left(A_t K_t\right)^\alpha L_t^\eta$$

where $A$ stands for the capital productivity technological shock[9], $K$ for

[9] Note that we could rewrite the production function as $Y = \widetilde{A} K^\alpha L^\eta$ where $\widetilde{A} = A^\alpha$ and define $\widetilde{A}$ as the usual total factor productivity shock.

capital and $L$ for labor. Capital can be stocked and transferred to the next period at an exogenous rate of return $\rho$. If an agent dies his capital endowment is destroyed (we can interpret it as human capital). Since newly born agents have no capital and older agents have no labor endowment, there has to be some social arrangement through which capital and labor meet to produce.

There are two available technologies for the growth rate of capital which differ in their returns and volatility. I will call them "low risk-low return" and "high risk-high return" respectively. The technologies are defined by:

$$A_{t+1} = A_t \left(1 + \mu_j\right) + \varepsilon_{t,j}$$

$$\varepsilon_{t,j}\tilde{\ } F \ ; \left\{ F : F\tilde{\ } \left(0, \sigma_j^2\right) \text{ and } \sup_F \left[-\iota, \iota\right] \right\}$$

$$\begin{aligned} j &= LR, HR \\ \mu_{LR} &< \mu_{HR} \\ \sigma_{LR} &< \sigma_{HR} \end{aligned}$$

Every period agents have to choose first between two types of social organizations. One is what we call the "Chinese style lineage society" and the other one the "English style individualistic society". Once agents have decided their social structure they produce and invest. Then they choose between the low risk and high risk technology. Finally a fraction ■ of the population dies and the technological shock is realized.

## 3.2 Social Organization

### 3.2.1 Lineage Structure

A lineage, $\Gamma$, is a finite group of agents that merge their endowments, share the output they produce and commonly decide which technology to use. The demographics of the lineage are identical to to the demographics of the population: that is, the age distribution is the same. Since the lineage is composed of a finite amount of agents each lineage may face a different mortality rate period by period (and therefore different capital depreciation rates). To avoid this problem, we introduce the continuum of populations. We assume that members of different populations reshuffle from one lineage to the other to keep the mortality rate constant across lineages. The reshuffling occurs only within lineages that have the same state variables, $\left(A_t^{\Gamma}, \sum_{i\in\Gamma} k_t\right)$, so that there is no change in the risk sharing structure[10]. The evolution of the lineage's capital stock becomes:

$$K_{t+1}^{\Gamma} = \lambda\left(K_t^{\Gamma}\left(1+\rho\right) + h_t^{\Gamma}\right)$$

where $h$ stands for investment and $X_t^{\Gamma} = \sum_{i\in\Gamma} X_t^i$. The capital productivity shock occurs at the aggregate level and is not idiosyncratic to the agent but to the lineage. This implies that the lineage cannot insure the technological risk within its members. Furthermore, there is no social institution to insure that risk away.

There is a majority rule to decide the technology that will be used next period. Each member has a share of votes, $v_t^i$, that depends on the capital share after investment is decided. This can be interpreted as a reduced form of a more complicated bargaining process where the capital share determines the relative power within the group.

$$v_t^i = \frac{K_t^i + h_t^i}{K_t^{\Gamma} + h_t^{\Gamma}}$$

Two considerations have to be made. First, considering the capital share after the investment decision is made gives some power to the newly born agents, which own the labor endowment but no capital at time $t$. Second, this rises a strategical component to the investment decision. The investment strategy could be affected by the desire to promote a certain technological regime.

**Claim 1** *A rule* $\chi^* = \left\{(\chi_1, \chi_2, \chi_3) : \sum_i \chi_i = 1\right\}$ *for output sharing that provides a fraction of total output* $(\chi_1, \chi_2, \chi_3)$ *for the newly borns, young*

[10]The reshuffling should not only depend on the aggregate capital stock, but on each cohort's capital stock. This would make the problem substantially harder to solve because the state space would expand considerably. However, since the young adults and the old agents will have their preferences alligned, all the information can be summarized in terms of the aggregate capital stock.

*adults and elderly respectively, if the agent's endowment is and has always been provided to the lineage, and zero otherwise, is sustainable.*

***Proof.*** *Not providing the endowment to the lineage implies a zero consumption period and due to the Inada condition this will be avoided by the agent* ■

Given that $u$ is DRRA, an increasing or decreasing profile of the $\chi's$ could harm our risk aversion argument. Equal shares prevents us from discretional impacts on risk aversion, so we will assume the pie will be equally divided among lineage's members.

Conditional on the regime choice, the program for the newly borns, the young adults, and the elderly becomes:

$$\begin{aligned} V_1^C\left(A_t^\Gamma, k_t^\Gamma \middle|\ J_t\right) &= \max_{k_{t+1}^1} u^y\left((1-\lambda)\left(A_t^\Gamma k_t^\Gamma\right)^\alpha - k_{t+1}^i\right) \\ &\quad +\beta\lambda E_{A_{t+1}|A_t} V_2\left(A_{t+1}^\Gamma, k_{t+1}^\Gamma \middle|\ J_{t+1}\right) \end{aligned} \tag{1}$$

$$\begin{aligned} V_2^C\left(A_t^\Gamma, k_t^\Gamma \middle|\ J_t\right) &= \max_{k_{t+1}^2} u^y\left((1-\lambda)\left(A_t^\Gamma k_t^\Gamma\right)^\alpha - \left(k_{t+1}^i - k_t^i(1+\rho)\right)\right) \\ &\quad +\beta\lambda E_{A_{t+1}|A_t} V_3\left(A_{t+1}^\Gamma, k_{t+1}^\Gamma \middle|\ J_{t+1}\right) \end{aligned} \tag{2}$$

$$\begin{aligned} V_3^C\left(A_t^\Gamma, k_t^\Gamma \middle|\ J_t\right) &= \max_{k_{t+1}^3} u^o\left((1-\lambda)\left(A_t^\Gamma k_t^\Gamma\right)^\alpha - \left(k_{t+1}^i - k_t^i(1+\rho)\right)\right) \\ &\quad +\beta\lambda E_{A_{t+1}|A_t} V_3\left(A_{t+1}^\Gamma, k_{t+1}^\Gamma \middle|\ J_{t+1}\right) \end{aligned} \tag{3}$$

where $V_1^C$, $V_2^C$ and $V_3^C$ are the value functions for the newly borns, the young adults and the elderly respectively; $J$ is the technological regime and $k_{t+1}^i$ for $i = 1, 2, 3$ is the capital that each of the three types of agents decides to hold next period (conditional on surviving).

**Claim 2** *For very low productivity values all the agents have their preferences alligned and choose the low return-low risk technological regime. For intermediate producivity values the newly born favor the high return high risk technology, and for very high productivity values, preferences are realligned again and all the agents support the high return regime.*

***Proof.*** *Note that the voting decision depends on the comparison between the two technological regimes, that can be viewed as two lotteries. The vote of the newly born agents depends on:*

$$sign\ E_{A_{t+1}|A_t} V_2\left(A^{\Gamma}_{t+1}, k^{\Gamma}_{t+1}\right|\ HR\left.\right) - E_{A_{t+1}|A_t} V_2\left(A^{\Gamma}_{t+1}, k^{\Gamma}_{t+1}\right|\ LR\left.\right) \qquad (4)$$

*While the vote of the of the young adults and the elderly depends on:*

$$sign\ E_{A_{t+1}|A_t} V_3\left(A^{\Gamma}_{t+1}, k^{\Gamma}_{t+1}\right|\ HR\left.\right) - E_{A_{t+1}|A_t} V_3\left(A^{\Gamma}_{t+1}, k^{\Gamma}_{t+1}\right|\ LR\left.\right) \qquad (5)$$

*Note first that young adults and the elderly always have their preferences alligned. The choice of the technological regime impacts on next period utilty, where both types of agents will have the old type of preferences. Secondly, since all the agents have DRRA utility functions, given the state variables* $\left(A^{\Gamma}_t, k^{\Gamma}_t\right)$*, there is a threshold productivity value,* $\left\{\overline{A}^y, \overline{A}^o\right\}$ *for* (4) *and* (5) *respectively, such that for any value below that threshold agents choose the low risk regime and for any value above that threshold they choose the high risk regime. Since old agents are more risk averse than young agents* (4) *is always higher than* (5) *and therefore* $\overline{A}^y < \overline{A}^o$*. This determines three zones. Given* $\left(A^{\Gamma}_t, k^{\Gamma}_t\right)$*, if* $A^{\Gamma}_t < \overline{A}^y$*, there is unanimity and all the agents favor the low risk-low return regime. If* $A^{\Gamma}_t \in \left[\overline{A}^y, \overline{A}^o\right]$ *newly borns favor the high return regime while the rest of the agents the low return regime. If* $A^{\Gamma}_t > \overline{A}^o$*, all the preferences are realligned again and everybody favors the high return regime.* ■

Given $\left(A^{\Gamma}_t, k^{\Gamma}_t\right)$, in the regions where preferences are fully alligned agents will choose their investment decisions according to their program given by (1), (2), and (3). Transitions from the low to the high regime will bedetermined by the elderly if, given $\left(A^{\Gamma}_t, k^{\Gamma}_t\right)$ and $A^{\Gamma}_t \in \left[\overline{A}^y, \overline{A}^o\right]$, it is not optimal for the newly born to over-invest to achieve a regime change. If the utility of overinvesting and obtaining a regime change next period is lower than the utility of remaining within the current regime and investing according to (1):

$$\begin{aligned} & u^y\left(\left(1-\lambda\right) A^{\Gamma}_t \left(k^{\Gamma}_t\right)^{\alpha} - \left(\overline{k_{t+1}} - \lambda k^i_t \left(1+\rho\right)\right)\right) + \beta\lambda E_{A_{t+1}|A_t} V_2\left(A^{\Gamma}_{t+1}, k^{\Gamma}_{t+1}\right|\ HR\left.\right) \\ < \ & V_1\left(A^{\Gamma}_t, k^{\Gamma}_t\right| LR\left.\right) \end{aligned}$$

where $\overline{k_{t+1}}$ is the level of capital that the newly born has to achieve for the regime to change[11]. For the parameter values that will be chosen in the simulation section, it is not convenient for the newly born to over-invest and produce a regime change. The newly born never "overaccumulate" capital and regime transitions depend merely on the elderly and therefore take much longer to occur in comparison to the nuclear family regime, where each agent bears her own decisions. Depending on the parameter values, the switch in the growth rates can be different in England than in China. There can be one initial stage were only the newly born adopt risk and then the rest of the groups join them. According to our parametric assumptions, the change in the growth rate will be discrete and will happen only once.

### 3.2.2 Individualistic Structure

The main difference between the individualistic and the lineage society is the capital market. Individuals within this social structure do not form lineages nor meet each other repetitively to produce. Newly born agents use their labor endowment and rent capital to produce. They consume and save for next period, where their income comes from the return they obtain in the capital market on the capital they have accumulated. Young adults and elderly agents rely solely on their capital endowment as an income source. To simplify the analysis we assume each economy is a small open economy[12], and take the real interest rate, $r$, as fixed. Markets are incomplete, and there is only one asset, capital, that is traded and that provides the same rate of

[11] Given the majority rule and the allignment of the preferences of the young adults and the olds, newly born agents have to achieve at least 50% of the shares to obtain a regime change. Let $\alpha_1$ be the shares of the newly born:

$$\alpha_1 = \lambda \frac{h_t^1}{K_t^\Gamma + h_t^\Gamma} > 1/2$$

$$\Leftrightarrow k_{t+1}^1 = h_t^1 > \frac{K_t^\Gamma + \lambda^2 h_t^2 + \left(\frac{1}{1-\lambda} - \lambda - \lambda^2\right) h_t^3}{\lambda}$$

$$\Leftrightarrow k_{t+1}^1 > \overline{k_{t+1}}$$

[12] Closing the capital market and having an endogenous interest rate could be very interesting. A decline in the interest rate could potentially foster further growth through extra capital accumulation (and a secondary effect through the adoption of riskier technologies in future periods). We keep the interest rate exogenous to keep the model more parsimonus.

return in every state of the world. The only source of uncertainty comes from the techonological choice on capital productivity.We assume that the initial productivity level is drawn randomly from the population distribution of productivities. This can be interpreted as an exogenous transimission of knowledge to the new generations.

Note that newly born agents in the first period maximize the profit of their production unit:

$$\begin{aligned}\pi\left(A_t, r\right) &= \max_{k_t}\left(A_t k\right)^{\alpha} - r k_t \\ &= \left(\frac{A_t \alpha}{r^{\alpha}}\right)^{\frac{1}{1-\alpha}}\left[A^{\alpha(2-\alpha)}\alpha^{\alpha} - 1\right]\end{aligned}$$

The program for the newly born, young adult and old respectively becomes:

$$V_1^I\left(A_t^i, k_t^i \middle| \ J_t^i\right) = \max_{k_{t+1}} u^y\left(\pi\left(A_t^i, r\right) - k_{t+1}^i\right) + \beta\lambda E_{A_{t+1}|A_t} V_2\left(A_{t+1}^i, k_{t+1}^i \middle| \ J_{t+1}^i\right)$$

$$V_2^I\left(A_t^i, k_t^i \middle| \ J_t^i\right) = \max_{k_{t+1}} u^y\left(r\left(1+\rho\right)k_t^i - k_{t+1}^i\right) + \beta\lambda E_{A_{t+1}|A_t} V_3\left(A_{t+1}^i, k_{t+1}^i \middle| \ J_{t+1}^i\right)$$

$$V_2^I\left(A_t^i, k_t^i \middle| \ J_t\right) = \max_{k_{t+1}} u^o\left(r\left(1+\rho\right)k_t^i - k_{t+1}^i\right) + \beta\lambda E_{A_{t+1}|A_t} V_3\left(A_{t+1}^i, k_{t+1}^i \middle| \ J_{t+1}^i\right)$$

where $V_1^I$, $V_2^I$ and $V_3^I$ are the value functions for the newly borns, the young adults and the elderly respectively; $J$ is the technological regime and $k_{t+1}^i$ is the capital that agent $i$ decides to hold next period (conditional on surviving).

**Claim 3** *Under the individualistic society, high risk high return technologies are adopted early on.*

**Proof.** Note first that given $(A_t^i, k_t^i)$ there is also a threshold $(\underline{A}^o, \underline{A^y})$ such that newly borns prefer the high return high risk technology if and only if $A_t > \underline{A^y}$, and the rest of the agents prefer the risky technology if $A_t > \underline{A^o}$, where again, $\underline{A^y} < \underline{A^o}$. The main difference with the lineage structure is that agents do not jointly decide the technological regime. This implies that for an interest rate $\widetilde{r}$, such that $\underline{A^y} = \overline{A^y}$, if $A_t^\Gamma = A_t^i \in \left[\overline{A^y}, \overline{A^o}\right]$, the newly born agent $i$ in the individualistic society will choose the high risk high return technology, while under the lineage structure the low risk low return technology will be chosen.

**Claim 4** *The threshold for the young under the nuclear family structure is smaller than for the old under the kinship structure: $\underline{A^y} < \overline{A^o}$, and therefore the adoption of riskier technologies occurs faster under the nuclear family structure.*

■

## 3.3 Poor Law

We interpret the poor law as an exogenous shift in the distribution of the technological shocks which makes less favorable outcomes more unlikely to happen. One possible definition could be that the king makes sure that no one gets a shock below a certain threshold:

$$\varepsilon_{t,j}^{PL} \tilde{\ } F_{PL} \text{ with } \left\{ F_{PL} : F_{PL} \tilde{\ } \left(0, \sigma_j^2\right) \text{ and } \sup_F \left[-\iota_{PL}, \iota\right] \right\}$$

$$\text{where } -\iota_{PL} > -\iota,\ F\left(-\iota_{PL}\right) > 0 \text{ and } F_{PL}\left(x\right) = F\left(x\right)\ \forall x > -\iota_{PL}$$

The problem with this definition is that $E\left(\varepsilon_{t,j}^{PL}\right) > 0$, and therefore the Poor Law not only implies a change in the risk structure but also a wealth effect. To keep the introduction of the poor law wealth neutral, we will assume that the only impact of the Poor Law is reducing technological volatility, that is:

$$\varepsilon_{t,j}^{PL} \tilde{\ } F_{PL} \text{ with } \left\{ F_{PL} : F_{PL} \tilde{\ } \left(0, \sigma_{j,PL}^2\right) \text{ and } \sup_F \left[-\iota, \iota\right] \right\}$$

$$\text{where } \sigma_{j,PL}^2 < \sigma_j^2$$

This is a simplification of a case that could be micro founded by an ex post income tax that the king establishes where wealthy people subsidize poor people.

Since agents face now less risk, productivity threshold values (for both regimes) are reduced:

$$\begin{aligned} \overline{A}^y_{PL} &< \overline{A}^y, \overline{A}^o_{PL} < \overline{A}^o \\ \underline{A}^o_{PL} &< \underline{A}^o, \underline{A^y}_{PL} < \underline{A^y} \end{aligned}$$

And therefore agents are eager to invole in the riskier technology earlier on, fostering the Industrial Revolution.

# 4 Simulation

There is one main result that we will show in this section. For the same set of parameter values, once the economy is shocked with the Poor Law, the English agents adopt the riskier technology while the lineages keep using the same low risk low return technology forever. We will describe and justify first the set of parameter values we use and then show the numerical results we obtain.

We use a CES utility function and introduce a minimum consumption requirement that is different when young than when elderly:

$$u^i = \frac{\left(c - \overline{c}^i\right)^{1-\sigma}}{1-\sigma}$$

where $\overline{c}^y < \overline{c}^o$. The consumption requirement is a technicality to make elderly agents be more risk averse. Health issues could substantiate larger consumption requirements for elderly agents. Note that the utility function has the DRRA property:

$$R^i_r = \sigma \left( \frac{c}{c - \overline{c}^i} \right)$$

We let the young agents have a consumption requirement ten times smaller than the old agents to make them substantially less risk averse (especially for low income realizations).

Macroeconomist tend to set the common risk aversion parameter $\sigma$ in the boundaries of $[2, 5]$. Researchers in the Industrial Organization field choose numbers closer to 10. We choose a number of 7.5, in the high end of the distribution, to highligh the effects of the risk sharing hypothesis. The results are not sensitive for any risk aversion coefficient between 5 and 8.

Each period lasts for twenty years in our simulation. Agents are newly born in the 0-19 cohort, young adults in the 20-39 cohort and elderly for the rest of the cohorts. We set $\beta$ as .60268, which implies an annual discount factor of .975. Agents die with an unconditional probability $\lambda = 1/2$. Although the distribution yields agents that live forever, the probability of being older than 100 years old in our model is 3.125%. This is clearly unrealistic, but keeping an unconditional death probability simplifies the model and keeps the fertility issue as silent as possible.

The return on the technologies is substantially different. The low risk low return technology has a zero return, while the high risk high return technology has a period return of 22.019% which implies a 1% return a year. We let the low risk low return technology have a thirty times smaller shock than the high risk high return technology to make our point stronger. We set $a_1 = 0.01$ and $a_1 = 0.3$.

We set the technological transferral rate $\rho = 1$, so depreciation comes only through the death of agents and there is no positive return saving technology outside the capital markets. We let the real interest rate for the period be $r = 1.1$. None of our simulations is sensitive to that result. Finally, the capital share $\alpha = .4$. Capital share measures lie in between 1/3 and .9 when including broad measures of human capital for current technologies. If we assume broad measures of human capital for technologies used in the $XVIII$ century we could obtain a number closer to ours. The results in the simulation are not sensitivy for capital shares in the range of .4 and 2/3.

| **Parameters** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $c_y$ | $c_o$ | $\sigma$ | $\beta$ | $\lambda$ | $\gamma_1$ | $\gamma_2$ | $a_1$ | $a_2$ | $\rho$ | $r$ | $\alpha$ |
| .1 | 1 | 7.5 | (.975ˆ20) | 1/2 | 0 | (1.01ˆ20) − 1 | 0.01 | 0.3 | 1 | 1.1 | .4 |

We set an arbitrary initial capital and technological productivity and let the economy approach its steady state level. Then we introduce the Poor Law in England and the adoption of the riskier technology happens immediately. The policy functions for the newly born agents are different than for the rest of the population. Newly born agents are more inclined to take further risk than the rest of the population.

[INCOMPLETE]

# 5 Conclusion

Lucas (2002) points to the implications of the fact that "modern theories of economic growth ... have failed to deal adequately with the change in human condition that the industrial revolution represents." The source of this failure is that these theories are "built around a positive rate of technological change, either simply assumed or generated as an equilibrium outcome by the assumption of constant or increasing returns to the accumulation of knowledge." This paper responds to the need to endogenize the rate of technological changes. It demonstrates the theoretical possibility that the rate of technological change is endogenous to self-enforcing risk-sharing institutions. Different self-enforcing risk-sharing institutions imply distinct rates of technological changes.

Our analysis focused on risk-sharing institutions resembling those that prevailed in pre-modern China and England. It demonstrates analytically that risk-sharing institutions can determine whether the rate of technological change will be positive, and that in societies in which kinship groups dominated by their elders provided insurance, industrialization was less likely to transpire. In an individualistic society in which the young make their own decisions, government policy fostering insurance was more likely to cause industrialization. Our simulation demonstrates that the Poor Law – which provided better insurance in individualistic England – may have been the factor that led to positive rates of technological change and industrialization.

Hence, it may well be that distinct risk-sharing institutions partially explain the age-old question in growth theory and economic history, "why was England first?" Moreover, our analysis suggests that the answer to the question of "why was Western Europe second?" may be that it was not far behind England in terms of its social structures and risk-sharing institutions. Risk-sharing institutions might still be relevant in determining the rate of productivity growth. In contemporary Africa, parents did not adopt Pareto-improving technologies that would have reduced their control over their children and hence the likelihood of old-age support (e.g., Hoff and Sen. 2005).

The analysis also reaffirms that economic institutions – in this case, risk-sharing institutions – are not independent of the social and political features of the society under consideration. Social structures in Europe changed in response to the Church's moral authority. The absence of kinship groups and the political conflict between the Church and state led to particular risk-sharing institutions. Cultural and political considerations similarly determined China's social structures and hence who made economic decisions and the resulting risk-sharing institutions. Economic institutions, in other words, reflect economic considerations as well as cultural, social and political factors (Greif 1994, 2007). Enriching unified growth theory by incorporating such factors in the analysis has the promise to further enhance our understanding of the "change in human condition that the industrial revolution represents."

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