Risk, Institutions and Growth: Why England and Not China?

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Abstract

We analyze the role of risk-sharing institutions in transitions to modern economies. A higher investment in the formation of new, productivity-enhancing knowledge initiates a transition. Individual-level risk and positive externalities imply a market failure and under-provision of new knowledge. Distinct risk-sharing institutions – even those providing the same level of insurance – can lead to different growth trajectories. Risk-sharing institutions, however, were historically selected irrespectively of their growth implications. A simulation of England's and China's pre-modern risk-sharing institutions predicts a transition only in England. The analysis builds on the existing literature but departs from it by emphasizing market failure, new knowledge, and institutions. Similarly, our analysis is the first 'pure' choice-based model of transition in the sense that it neither depends on an exogenous shock nor on time-dependent state variables.

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"The transition from stagnation to growth is largely an inevitable outcome of the process of development." Oded Galor, 2007, p. 472.

"Theories of economic growth have failed. These theories are built around a positive rate of technological change, either simply assumed or generated ... by ... assumption." Robert E. Lucas Jr. 2002, p. 110.."

1 Introduction

What has led to transitions from pre-modern economies to modern economies? In multiple-equilibria growth models, a low-growth economy is a stable equilibrium because decreasing relative risk aversion implies that agents are too risk-averse to choose the modern, high-risk, high-return technology. A transition occurs due to "accidents and good fortune ... in the initial levels of human capital and technology, and subsequent productivity and other shocks" (Becker, Murphy and Tamura 1990, p. s14). In endogenous-transition models, low-growth equilibria are unstable and a "transition from stagnation to growth is largely an inevitable outcome of the process of development" (Galor, 2007, p. 472).[1] In particular, time-dependent changes in relative prices, technology, or wealth trigger a transition. These models have been criticized, respectively, for failing to explain transitions because they either invoked accidents (Galor 2005, pp. 176-7) or "are built around a positive rate of technological change, either simply assumed or generated as an equilibrium outcome by the assumption of [for example] constant or increasing returns to the accumulation of knowledge" (Lucas 2002, p. 110).

This paper theoretically analyzes and historically evaluates endogenous transitions in the absence of changes in fortune, time-dependent variables, or even knowledge of modern technology. It focuses on risky activities leading to new, productivity-enhancing knowledge because in the past the epistemological basis of technology was narrow (Mokyr 2002) and the creation and implementation of such knowledge required cultivators, producers, and traders to take risks and experiment.[2] Yet, due to high risk aversion, socially beneficial risk-taking is not likely to be individually rational prior to a transition. The introduction of a risk-sharing institution that makes risk-taking

[1] Kremer 1990; Jones 1999; Galor and Weil 2000; Gollin, Parente and Rogerson 2002; Galor 2005.

[2] Acemoglu and Zilibotti (1997) examine the relations between the indivisibility of risky projects, diversification, and growth.

individually rational, can lead to new knowledge, higher productivity and initiate a transition. In our analysis, whether a transition transpires directly depends only on choices on the social and individual levels.

We model this argument using an OLG, 'technology transition' framework (Hansen and Prescott 2002) in which economic agents choose how to employ their capital.[3] An agent's choice of how to employ his capital determines the probability that new knowledge will be generated. Employing the 'traditional,' technology is less likely to generate new knowledge but is also less risky. Experimenting and exploring new possibilities is more risky but is more likely to generate new knowledge. This knowledge increases the capital productivity of both the agent who discover it and of subsequent generations. A pre-modern economy is one in which most agents choose the 'traditional, low-return, low-risk technology (henceforth LR technology) and the rate of productivity growth is correspondingly low. In a modern economy, all agents choose to experiment, to employ the high-return, high-risk technology (henceforth, HR technology) and the rate of productivity growth is high. In a transition, the number of agents choosing the HR technology increases over time, causing an increase in the rate of productivity growth.

Positive externalities implies that agents will employ less capital than socially optimal in the HR technology. Moreover, decreasing relative risk aversion implies that the LR technology will be chosen by sufficiently poor agents. If sufficiently many agents are poor, a transition will therefore will not transpire and the economy stagnates. A risk-sharing institution can mitigate the impact of low wealth and risk aversion on some agent's technological choices and initiate an endogenous transition. More specifically, a risk-sharing institution that sufficiently increases risk-taking, causes a transition. For reasons discussed below, two institutions that provide the same risk-sharing, can nevertheless have different risk-taking implications

This causal relation between new knowledge, non-market institutions, and transitions is intuitively appealing for two reasons. First, it does not rely on the assumption, common in growth models, that the economic agents know the 'modern' technology or that society posses the human capital necessary for a modern economy. Modernization involves discovering this technology and human capital. The analysis here assumes only that the economic agents know the traditional technology but recognize that deviations are risky but

[3] Analytically, we focus on capital productivity rather than human capital to capture choices with positive externalities (e.g., cultivation techniques).

potentially rewarding. Similarly gratifying is the observation that transition does not depend, as common in growth models, on incentives provided by changes in market prices. An integral part of a transition is the development of the knowledge required for improving markets.

We evaluate the historical relevance of transitions' institutional conditionality by modeling China's and England's pre-modern institutions, simulate their implications and qualitatively evaluate their time-series and cross-section implications. In both economies, compassion and concern with social order led to effective, yet distinct, risk-sharing institutions. In China, poor relief was predominantly provided by lineages (clans) headed by their elders. In England, the state gradually displaced the Church and voluntary associations as the main provider of poor relief. The Old Poor Law of 1601 formalized the system which, with some modification, prevailed to 1834.[4] Similar transitions transpired elsewhere in Europe but England's system was particularly effective (Solar 1995).

In each state, these institutions were not selected by their impact on growth. If these risk-sharing institutions were aimed at promoting growth, the factors limiting the ability to create better institutions, rather than the details of the resulting institutions, would have been the ultimate cause of different growth trajectories. Yet, the details of each of these institutions reflect compatibility with the institutional elements already in existence.[5] A clan-based risk-sharing institution evolved in the collectivists, lineage-based Chinese society while a state-based risk-sharing institution evolved in the individualistic English society. These particular institutions were selected because institutional dynamic is a historical process and not because of their growth implications. It is therefore appropriate to consider them as exogenous in examining their growth implications.[6] We present the historical processes that led to distinct institutions and why each institution was an equilibrium outcome among the economic agents.

The evolution of these particular risk-sharing institutions in each society,

[4] Voigtländer and Voth (2006) found that the Old Poor Law did not influence England's industrialization by increasing wages.

[5] These institutional elements were their distinct organization of the state, social structures (e.g., clans), and a beliefs system (e.g., regarding the elders' authorities). For the view that institutional dynamic is a historical process in which institutional elements inherited influence subsequent institutions, see Greif 2006, chapter 7.

[6] Institutions governing one transaction (i.e., poor relief and social order) tend to have unintended consequences on behavior in other transactions (i.e., risk-taking). Greif (2006).

highlights an interpretation of our analysis as bridging the view that transitions are due to luck and the view that transitions are inevitable. Transitions transpire when 'luck' creates the conditions under which economic agents find it beneficial to make the choices leading to is a positive rate of technological changes.[7] Luck did not come in the form of a random draw of knowledge or wealth. It came in the form of a historical process leading to institutions that fostered the creation of knowledge and thereby wealth. Transitions to a modern economy might, in particular, transpire neither due to the accident of good endowment nor because they were inevitable outcomes. Transitions were conditional on the luck of having *risk-sharing* institutions that encouraged productivity-enhancing *risk-taking* which increased the rate of productivity growth.

Our simulation and historical analysis confirm the importance of risk-sharing institutions in transitions to a modern economy. China's lineage-based institution implied more risk-sharing prior to the introduction of the Old Poor Law. Yet, it was relatively ineffective in promoting risk-taking because the lineage-based institution also changed the decision-making process. Lineages' elders had, by law and custom, strong influence on technological choices made by their lineages' young members. Because older people tend to be more risk averse than younger, the lineage-based institution led to less risk taking than would have been the case if the young were in charge.[8] Our simulation reveals that if the Chinese and the English institutions implied the same level of risk-sharing, an eight percent initial difference between the risk aversion of young and old was sufficient to prevent China from embarking on a transition to a modern economy. To initiate a transition, the Chinese institutions would have had to provide, roughly speaking, about three times better risk sharing than the English one.

Prior to the introduction of the Old Poor Law, England's risk-sharing

[7]Previous works pursuing this issue have focused on an endowment windfall due to the discoveries (e.g., Pomeranz 2000), better informal contract enforcement institutions and the enlightenment (Mokyr 2005, 2006), and higher mortality rates which increases per-capita income (Voigtländer and Voth 2006).

[8]Contemporary empirical analyses found that the elders are more risk averse. 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 twentieth-century decisions by Chinese peasants 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).

institutions were not conducive to initiate a transition either. The early seventeenth century transformation of England's risk-sharing institutions, however, fostered both risk-sharing and risk-taking assumed by the young. More specifically, the Old Poor Law directly insured the poor from the economic risk associated with the structural transformation associated with the transition. Insuring the poor reduced the risk to the wealthy from investing, discovering, and implementing new useful knowledge. By the middle of that century, as discussed below, England began the expansion leading to a modern economy. Risk-sharing institutions can influence if and when a transition to a modern economy transpires. Our analysis reveals that it may have been important in rendering England, rather than China, the first to become a modern economy.

Much more has to be done to develop and evaluate this conjecture, China and England differed by more than risk-sharing institutions, and modernization requires more than only supporting risk-sharing institutions.[9] Our analysis is only aimed at demonstrating the historical relevance of the causal relations between risk-sharing institutions, knowledge, and transitions. It is reassuring, nevertheless, to note the empirical confirmation of the model's qualitative time-series and cross-section predictions. Our analysis accounts for observations that are difficult to reconcile when viewing transitions as either accidental or inevitable. Among these are the surge in China's contributions to new knowledge under the Song Dynasty (960-1279), their subsequent decline, England's leadership in innovations rather than inventions during the Industrial Revolution, and the capacity of European states to rapidly imitate England.

The analysis supports the view that institutional distinctions were central, rather than epiphenomena, to transitions to modern economies. Transitions' institutional conditionality is a contested issue in economic history and growth theory. Economic historians have traditionally emphasized England's growth-enhancing institutions, such as limited government, better labor markets, and a social environment conducive to innovations (e.g., North and Weingast 1989; Mokyr 1990, 1999, 2007; and Solar 1995). More recent literature, however, has down-played institutions' role, claiming that intra- and inter-European institutional distinctions were insignificant on the eve of

[9] Particularly relevant to our argument are differences in cultural attitudes toward risks and inventions (e.g., Mokyr 2002, 2006) and the institutional foundations of the market (Greif 2005) .

the Industrial Revolution (e.g., Craft 1977; Pomeranz 2000; Clark 2005).

Growth theory emphasized the importance of accidents in determining the historical sequence of transitions. The “Industrial Revolution transpired due to an exogenous increase in research productivity" (Kremer 1990, p. 706). Institutions have been considered to impact, at most, the sequence of transitions but not the process leading to them. "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" (Hansen and Prescott 2002, p. 1215; and see Galor 2005, p. 178).

Our analysis suggests that institutions play a larger role in transitions than influencing the rate in which a universal growth process transpires. Institutions structure processes of choice thereby determine learning and growth-trajectories. More generally, the premise of growth-theoretic models is that the relevant decision-makers are individuals interacting in markets. Our analysis suggests that transitions depended on non-market institutions provided by the social level, the state and social structures (Greif 2005). Such dependence is reasonable given that such institutions are even important in modern market economies.

The rest of the paper is as follows. 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 Social structures, Risk-Sharing Institutions and Knowledge

Because in pre-modern economies, insurance against idiosyncratic individual-level risks were not provided by the financial market, it is appropriate to focus on non-market, risk-sharing institutions which, over the last millennium, evolved in different ways in China and England. Three observations about this evolution are presented in this section. They underpin the assumptions we later make in modeling these risk-sharing institutions and this modeling also exposes why these institutions were self-enforcing. First, lineages, dominated by their elders, prevailed in pre-modern China, but not England. More economic choices involving risk-taking were made by elders. Second, after 1601 the main risk-sharing institutions in these countries were state-based in England and lineage-based in China. Third, risk-sharing institutions influenced risk-taking and hence the creation of new knowledge.

2.1 Social structures

By 1000 AD, social structures in England and China had already evolved differently. In England and Europe more generally, large, kin-based social structures such as lineages and tribes declined, while in China they gained dominance as economic and social units.

The elimination of large, kin-based social structures in Europe was due to the marriage dogma adopted by the Church in the fourth century. The adoption of this dogma may had been aimed at dissolving kin-based social structures to facilitate control by the Church (Goody 1983; Greif 2006, 2007). The marriage dogma adopted by the Church 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 and prohibited unions without the bride's explicit consent.[10] Kin marriages, particularly among cousins, and parents' ability to retain kinship ties through arranged marriages were historically important means of maintaining kinship groups.

The European family structures did not evolve monotonically toward the nuclear family, nor was their evolution geographically and socially uniform. Yet, various evidence indicates that by the late medieval period the nuclear family became the norm in Western Europe (e.g., Mitterauer et. al. 1982; Goody 1983; Ekelund et. al. 1996;Herlihy, 1985; Greif 2006, chapter 8). The (Germanic) Salic law of the sixth century denied legal rights to anyone not affiliated with a large kinship group. 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, suggesting that kinship groups could no longer be held accountable as was the case when the Salic law was specified. Indeed, already by the eighth century the term family among the Germanic

[10] 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.

tribes denoted one's immediate family. Tribes and lineages, by and large, were no longer institutionally relevant (Guichard and Cuvillier 1996).

Quantitative evidence from later centuries also reveal a 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 (e.g., Scotland).

The nuclear family, a couple and their unmarried children, was also a basic unit of social organization in pre-modern China. But larger, kin-based social structures were common. Many of those with sufficient means maintained larger households, either in the form of a 'stem' or an extended family. A stem family included parents and at least one married son and his family and averaged ten people (Fei and Liu 1982). 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 family compound, had common property and an internal dispute-resolution mechanism. Such larger households were culturally esteemed and economically beneficial to their members, practically because they consolidated assets and local political power under family control.

Larger kinship groups were common in China as well and remained culturally, socially, politically and economically prominent to the modern period.[11] Indeed, the ideology and practice of patrilineal descent, filial pity, and ancestor worship was the hallmark of Chinese society and culture (e.g., Freedman 1958). Furthermore, social and economic relations were commonly kinship-based and lineages provided members with local public goods such as protection and education (e.g., Hamilton 1990). The state, whose magistrates were positioned at the county level and above, used kin-based organizations for tax collection and considered male descendants of a household a jointly liable tax unit.

The structure of Chinese kin-based social structures evolved over time and was not uniform over space. In particular, there was a gradual shift from communal families to lineage organizations. The communal family are

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

the kinship group referred to the most during the Tang (618-690, 705-907) and the Song (960-1279) dynasties. These were domestic units that had not divided – in terms of property or membership – for five, six, or even ten generations. Some communal families included hundreds and even thousands of members. 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 but we have no quantitative measure of how many communal families existed at any point in time. Given the complexity of supporting, organizing and maintaining the coherence of such large groups, really large communal families must have been relatively rare and it seemed that they gradually vanished.[12]

After the Song dynasty (960-1279), lineage organizations became common. These looser associations of relatively large numbers of kin "were the predominant form of kinship organizations in late imperial China" (Ebrey and Watson, 1986, pp. 1, 6; Watson 1982). Detailed information on the share of the population with lineage affiliation is not available but lineages were common in the south of China, were less common at the center and least common in the north of China.

Fathers exerted various degrees of authority even over their adult children and controlled the family's assets. In Imperial China, "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" (Chen 1999, pp. 250-1). The preferences of the elders dictated the economic actions of young adult. In sharp contrast, long before the 17th century under English law and customs, adult sons were not under their fathers' authority.

[12]By tracing clans' life-cycle, Fei and Liu (1982, p. 399) concluded that the critical maximum size (CMV) of a lineage is about I,400 males and females which is about 300 families. Abramitzky (2008) presents an empirical analysis of contractual problems in large, risk-sharing organizations.

2.2 Risk-sharing institutions

Risk-sharing institutions prevailed in all pre-modern stable societies. Indeed, risk-sharing institutions were means to maintain social order and thereby a society's stability. Because risk-sharing institutions were not designed to promote growth but stability, their growth implications were unintended. It is therefore appropriate to consider the details of risk-sharing institutions as exogenous to their impact on growth. These details were endogenous to these societies' circumstances and social organizations. In England and China, the absence and presence of large kinship groups let to the development of distinct risk-sharing institutions. From the early 17th century, the state in England provided for the poor while in China, poor relief was provided by kin-based groups to the modern period.

More specifically, prior to the 16th century, Europeans relied on various non-state risk-sharing institutions. In particular, secular and religious organizations – 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 and disability assistance. In the late medieval period, the total capacity of England's monasteries for grain storage was more than was required to sustain the Kingdom's population for a year (Fenoaltea 1976). In the early 16th century, the majority of the commoners in England belonged to fraternities and guilds that provided social safety nets (Richardson 2005). The same pattern seems to have prevailed elsewhere in Europe (Reynolds 1984; Brenner 1987). Getting relief from these risk-sharing institutions was, however, uncertain as they were either voluntarily provided by charity organizations (e.g., by the Church) or cooperatively financed by working people without much wealth.

The conflicts associated with the rise of Protestantism in the 16th century terminated this system of poor relief. Many of the corporations through which insurance was provided were associated with the Catholic Church and Protestant rulers dismantled them. In England, Henry VIII established the Anglican Church, dissolved the monasteries in 1536-40, and shut down all religious guilds, fraternities, almshouses, and hospitals in 1545-49. These actions "destroyed much of the institutional fabric which had provided charity for the poor in the past" (Slack 1990, p. 8). During the Counter-Reformation, Catholic rulers confiscated the properties of these corporations to finance their wars against Protestantism. Europe lost its system of poor relief.

Social order was undermined by the lack of an effective poor relief system and population growth pressured wages and increased poverty. States responded by creating alternative, state-based systems. Local administrative bodies within the European states, such as parishes and cities, were required by law to care for the poor. In England, the Poor Law Act of 1601 formalized the emerging alternative system which lasted, with some modifications, until 1834. Each parish was authorized and obliged to levy a property tax to care for the poor (Boyer 1990).

Shifting the responsibility for poor relief to the state (via local administrators) was a European phenomenon and poor relief systems similar to England's were established elsewhere in Europe (Geremek 1997; Jutte 1996; de Vries and de Woude 1997, pp. 654-664). Yet, for unknown reason, England was particularly effective in providing poor relief (Solar 1995). The English Poor Law system was more reliable and more generous than the continental ones. In England, expenses were financed through a variable poor rate on the assessed rental value of local real estate property and most aid was given without forcing the recipient to move to the poor house.[13] 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 legally while on the continent rights were vaguely defined, less credibly assured, and generally at the discretion of local authorities. Annual spending on poor relief in England were about 1 percent of the national income in the seventeenth century and about 2.5 percent at its peak during the 19th century. At that time, it supported about 11 percent of the population and may have boosted average income of the bottom 40 percent by 14 to 25 percent. 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. (Boyer 1990; 1999; Mokyr 2002).

Imperial China also experienced great diversity and changes in poor relief institutions.[14] The state sporadically financed general or medical aid to the old, poor, sick, and disabled. Buddhist monasteries and temples provided

[13]Those who financed the Poor Law had no legal rights to influence risk taking. Moreover, farmers who took risk (by specializing in grains) had the political power to trasnfer the cost of insurance on others. Boyer (1986).

[14]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.

medical service, fed the hungry and sheltered the aged and decrepit. Their support, however, was uncertain as they fed any poor including 'undeserving' ones. 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.

The major source of aid to the poor, the sick, and the aged were kinship groups. The role of communal and extended families in providing insurance is transparent from their internal organization. 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). The young provided labor while the elders controlled all assets and had the legal and customary rights to make communal decisions.

In many respects, the lineages were the functional successors of communal families. They similarly exerted considerable legal and customary control over their members, provided them with public goods such as education, held common property, and acted as social and political units. In pre-modern China a lineage "performs many functions related to education, ceremony, social security, and maintenance of law and order. Whereas now most of these functions are performed by the government, the clan was a primary social group (or organization) through which these functions were carried out before the art of government was perfected" (Fei and Liu 1982, p. 375).

After the eleventh century, if not before, lineages became the most common and reliable source of poor relief. The first lineage charitable was established by Fan Chung-yen (989-1052) and such estates were considered by the state and their members as the lineage's property. Yet, they were not organized or legally recognized as commonly owned corporations but were controlled and managed by the elders of the lineage's prominent families. Income was used to finance rituals and to provide members with education, income, and support for weddings, burials and illness. Members in poverty received additional benefits and sometimes free lodging. The state motivated lineages to care for its poor by considering it legally responsible for crimes committed by its members.

Common to these poor relief institutions in England and China is that they evolved irrespectively of their impact on economic growth but were shaped, in particular, by institutional elements inherited from the past. It is easy to see why a lineage-based institution prevailed in China but not in England. The English society was organized around families and not larger kin-based units. When Henry VIII dissolved the existing risk-sharing institutions during the Reformation, a lineage-based institution for risk-sharing was not much of an option. It was too costly, if not simply beyond the capacity of the state to create. It was less costly to rely on the parishes that pre-dated the Reformation. The institutional implications of the resulting state-based institution were to reinforce the family-based social organization and to undermine the development of contractual alternatives. The absence of kin-based or contractual alternatives increased the cost to the state of ceasing to provide poor relief.

China had different institutional elements by the eleventh century. Lineages prevailed and the state's administration was designed to interact with large kin-based social structures and not their individual members. Creating a state-based poor relief system was too costly given the alternative of relying on lineages. (In future versions we will examine why these systems were self-enforcing in the interactions among the economic agents.) .

2.2.1 Risk-taking and knowledge

Increase in useful knowledge underpinned pre-modern productivity growth. The putting-out system, the turnpike trust, drainage projects, the factory system, the steam engine, the New Husbandry, and the joint stock companies directly increased production and/or productivity. The ultimate source of this increase, however, was the knowledge of, or the correct belief in, their benefits to those who employed them. Similarly, new knowledge underpinned changes that eliminated factors, particularly institutional ones such as guilds and restrictions on trade, that inhibited growth.

It is risky to invest in discovering new, productivity-enhancing (technological, organizational, or commercial) knowledge. We often associate such investment with important inventions and consider patents as the means to mitigate the associated risks. Yet, patent systems were rare and ineffective in pre-modern economies. Even in England, an acceleration in patenting began only by 1757 (Sullivan, 1989) while the transition to modern growth began in the seventeenth century (Clark 2005). By and large, the new knowledge that increased productivity in pre-modern economies reflected the input of many individuals. These individuals took personal risk in 'deviating' from the conventional ways of 'doing things' but in doing so were also more likely to create productivity-enhancing new knowledge. Pursuit of risky innovations, inventions, and experimentations contributes to the knowledge base that others can acquire through observation, imitation, and education. Some of those who took this risk paid a high personal price. Johann Gutenberg, the European inventor of the printing press, ended his life in the poor house. Marie Curie, who pioneered the study of radioactivity, died immaturely from radiation. The knowledge they discovered was used by others.

The high personal risk associated with developing new knowledge during the English Industrial Revolution is suggested by the size of inheritances left by English entrepreneurs in modern and traditional occupations. The evidence is "consistent with the intuitively appealing hypothesis that entrepreneurs in the modern sector [from 1700 to 1850] suffered a higher failure rate, but when they struck it big, they did so on a larger scale" (Mokyr 2006, p. 31). The risk was sufficiently high that even wealthy individuals sometime lost all their property and ended relying on poor relief. One wealthy individual who took risk and paid dearly was "William Radcliffe, a Derbyshire 'improver of cotton machinery,' who bought Samuel Oldknow's mill after the latter's bankruptcy, and apparently died poor after a roller-coaster career; another was Samuel Hall, a cotton-spinner and engineer who died in 'very reduced circumstances.' The cotton merchant Thomas Walker had to live his final years from a bequest. Perhaps the most spectacular example of a failed entrepreneur was the highly eccentric Archibald Cochrane, earl of Dundonald, who spent his family's fortune on his ill-fated chemical business. More than anything, however, Cochrane was unlucky. Somewhat comparable was the case of Henry Fourdrinier, a well to-do London stationer who gambled on the main innovation in paper-making of his age, spent £ 60,000 on the business and failed in 1810. Both Cochrane and Fourdrinier are thus examples of a significant negative private return on entrepreneurship" (Mokyr 2006, pp. 24-5).

Given the personal risk of perusing new productivity-enhancing knowledge, it is reasonable to conjecture that risk-sharing institutions mattered. Indeed, the number of individuals of modest means that took the risk of creating new knowledge during the Industrial Revolution was far from negligible. There were 333 great inventors who were active after 1790 and were born prior to 1845 in Britain and the USA (that also had a Poor Law system).[15] Some 38 percent of the great inventors were of modest means judging by the fact that their fathers were farmers, low-skilled workers, or were neither

[15] A great Inventor is an individual who was included in biographical dictionaries because of his or her contributions to technological progress.

members of the elite nor had a declared occupation.[16]

Pre-modern risk-sharing institutions contribution to growth went beyond insuring one from economic risks. Their most important contribution was probably in mitigating the risk associated with social responses to new knowledge. In England, for example, members of the elite who were engaged in risky activities rarely ended up on the poor roles. Recipients of poor relief were generally individuals who never had substantial means (Boyer 1990). Yet, the Poor Law probably encouraged the wealthy to invest in the creation of new knowledge by reducing the likelihood that its implementation would elicit violent responses from the economically disadvantageous. The cost to the wealthy of risk-taking activities leading to new technological, organizational and commercial methods declined because the Poor Law secured those with meager means from the implied economic risks.

Indeed, despite the major transformation that England experienced during its transition, it was surprisingly peaceful and it is reasonable that the Poor Law contributed to this outcome.[17] The system supported between the 5 to 15 percent of the population at any time (Solar, 1995, p. 8) and transfer of such magnitude probably contributed a great deal to a relatively peaceful economic transition. "While there was some resistance to enclosure, the English were, by continental or Irish standards, quite easily separated from the land in the seventeenth and eighteenth centuries" (Solar 1995, p. 9). Similarly, there was relatively little popular resistance to other major transformations such as the decline in the putting out system, the introduction of hourly wage or the New Husbandry. England was remarkably peaceful during a transition that destroyed numerous traditional occupations and shifted risk toward the poor by increasing wage labor and eliminating many of their small landholdings and communal rights.

During the century that followed the Old Poor Law of 1601, the intellectual and organizational basis of the innovations leading to the industrial revolution was formed (Mokyr 2005). The seventeenth century also experienced a rise in the distribution and creation of new agricultural knowledge. Two

[16] Calculated from Khan (2008), table 3. The table precludes calculating the percent for Britain separately

[17] Charlesworth (1983) presents rural protest in Britain from 1548 to 1900. Protests were common but particularly when food price was high. He notes that In Lowland England "by the second decay of the seventeenth century ... lords were successful in ... sweeping away ... tenantry to make way for the large leasehold farm ... through the poor law, the attack on alehouses, the quarter session and the church court" (pp. 16-18).

measures for the formation and distribution of such knowledge are patents and technical manuals. Between 1550 and 1600, the number of patents was zero and the number of published farming technical manuals was 16. In the next 50 years the numbers increased to 28 and 43 respectively (Sullivan 1984, table 1).[18]

Changes in crops also provide evidence suggesting the contribution of the Poor Law to reducing the risks associated with transition. Grain production was highly profitable but its labor demand was seasonal. The Poor Law protected the livelihood of the laborers during the down season and reduced their incentives to seek employment elsewhere. This reduced the risk of labor shortage while, unlike higher seasonal wages, protected the farmers during years of low output prices. Furthermore, the law subsidized grain production by shifting the cost of seasonal unemployment to non-farmers and might have motivated a shift toward more risky economic pursuits more generally (Boyer 1986). Indeed, the particularly good data from early 19th century New York reveals a positive correlation between poor law expenditures and shift to wage labor in industry and agriculture (Hannon 1984).

3 Model

We model the rate of technological change as a function of risk-sharing institutions. The model highlights the factors influencing, under various institutions, the rate of technological changes. After presenting the model's basic structure, this section models the bench-mark case of a market economy and continue by considering two risk-sharing institutions. The first is a state-based institution which complements the market through redistribution to the poor and the second is a lineage-based institution under which economic agents are insured by their lineages, employ the technology chosen by their elders and share the output.

3.1 The basic structure of the model

Consider the following OLG, full information model. There is a continuum of agents in $\left[0, \frac{1}{1-\lambda}\right]$ each of whom might die with probability λ at the beginning

[18] Sullivan conjectured that the increase reflects popolation growth. The rate of population growth, however was much lower.

of each period.[19]. Agents are young for two periods in the first of which they are 'newly born' and in the second of which they are 'young adults'. An agent who dies is replaced by a newly born agent. Newly born agents are endowed with one unit of labor.[20] The rest of the agents have no labor endowment. Labor is supplied inelastically and the utility function for individual i is given by:

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

S is the space of states of the world, $s_{\tau+t}$ 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, $c_{\tau+t}^{i,\tau}$ is the consumption of agent i of generation τ in period $\tau + t$ and $C_{\tau}^{i,\tau} = \left(c_{\tau+t}^{i,\tau}\left(s_{\tau+t}\right)\right)_{t=0}^{\infty}$ represents every possible consumption value for each state of the world conditional on surviving, u^{y} is the utility function of a young agent (either newly born or young adult), u^{o} is the utility function of an old agent and β is the discount factor. The utility functions are both increasing, concave, continuously differentiable, satisfy the Inada conditions and have decreasing relative risk aversion (DRRA).

Only the labor-endowed agents (the newly born) can produce. The per-period production function is

$$y = (Ak)^{\alpha}$$

where Ak denotes units of effective capital where A is capital productivity and k is the capital level. A newly born agent combines effective capital with

[19] Our analysis abstracts from fertility issues to ease demonstrating that it does not depend on time-dependent variables and changes in relative prices. This implies, however, that we have to ignore some of the stylized facts regarding fertility. We do not dispute that fertility issues are important, but our focus is on the effects of risk sharing institutions on the adoption of risky technologies. We leave potential linkages between fertility and risk sharing for future work.

[20] Standard models let agents be young for only one period. Yet, the relevant choice in our model is next period's capital productivity, which is driven by next period utility function. If agents are young for only one period then age does not affect agents differently. To circumvent this issue we could change the timing, and let first agents determine their technological choice, then have the productivity realizations and finally let agents produce. This would have implied that young agents had to make decisions before they were born, which did not sound appealing to us.

her labor to produce and $\alpha < 1$ is the capital share. At the end of her first period, a newly born agent divides her income between consumption and saving in the form of capital. Young adults and elderly agents rent their capital, consume and save. Capital depreciates at rate δ per-period.[21]

The initial capital level of a newly born (her 'inheritance') equals the previous period's average capital level minus the depreciation rate and her initial capital productivity is the previous period's average. This process determining the initial capital productivity and capital levels creates intergenerational spillover effects in our fertility-free model. The initial productivity level of a young adult's capital equals the previous period's average productivity level.

Each agent i can use one of two technologies that affect her own future idiosyncratic capital productivity A^i_{t+1} and therefore her units of effective capital. The technologies differ in their return and risk. The first is "low-risk, low-return" (LR) and the second is "high-risk, high-return" (HR) where these risks and returns are with respect to future productivity of capital rather than current output. Formally, each technology j is defined by its expected return, μ_j, and its variance σ^2_j where

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

The expected productivity of agent i's capital next period, A^i_{t+1}, depends on her current productivity, A^i_t, the return on the technology she chooses, μ_j, and an idiosyncratic shock, $\varepsilon^i_{t,j}$. That is,

$$A^i_{t+1} = A^i_t \left(1 + \mu_j\right) + \varepsilon^i_{t,j}$$

where the distribution of the idiosyncratic shock for technology j is:

$$\varepsilon^i_{t,j}\tilde{}F : \left\{F : F\tilde{}\left(0, \sigma^2_j\right)\right\} \text{ where } j = LR, HR$$

The main distinction between this set-up and those common in growth theory is regarding the rate of productivity growth. In growth theory models,

[21] An alternative specification is that capital depreciates at rate one upon one's death and there is no intergenerational bequest. We simulated this model and our results remains qualitatively the same. This is because δ is already so large that the effect of the additional depreciation becomes of second order.

productivity growth is either exogenous, due to investment in education, or positively depends on a time-dependent increasing variable, such as population. In the current model, productivity growth is endogenous to the choice of technology.

3.2 Risk-sharing: the Market, the State and the Lineage

The rest of this section considers the growth implications of how labor and capital are matched and risk is shared. We simplify the analysis by considering a small open economy with a fixed, state independent rental rate of capital, r.[22] Consistent with the historical records, we assume that there is no insurance market and recognize that the allocation of both decision rights and income depends on the market, the state, and kinship relations. Our specification enables comparing and individualistic, market economy with or without a state-based insurance with an economy with a lineage-based insurance.[23] In the individualist, market economy labor and capital are matched by the market, each agent chooses technology for her capital, and have no insurance unless provided by the state. In the lineage-based society, labor and capital are matched within the lineage, elders choose among technologies, and lineage members insure each others.

3.2.1 Individualistic, Market Economy

Recall that a newly born agent produces by combining her labor with capital and the rental rate of capital is fixed at r. The profit-maximizing level of effective capital units is therefore $Ak = \left(\frac{\alpha}{r}\right)^{\frac{1}{1-\alpha}}$. Although all newly born agents have the same endowment of effective capital, denote, for ease of exposition, the capital productivity and capital of a newly born agent i born at time t by A_t^i and k_t^i, respectively. If a newly born is endowed with less than the optimal units of effective capital, $\left(\frac{\alpha}{r}\right)^{\frac{1}{1-\alpha}}$, she rents $A_t k_t$ units from the market and otherwise rents her excess capital in the market. The maximization problem for the newly born is $\max_{A_t k_t} \left(A_t k_t + A_t^i k_t^i\right)^{\alpha} - rA_t k_t$ implying the profit function of newly born agents in period t, $\pi_t\left(A_t^i, k_t^i, r\right) = (1-\alpha)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}} + rA_t^i k_t^i$

[22] We keep the interest rate constant and exogenous to have a parsimonus model.

[23] Markets prevailed in pre-modern China, of course, but our focus is on non-market relations among members of lineages.

which is continuous and linearly increasing with the agent's initial capital (k_t^i) and capital productivity (A_t^i).

We can now turn to the inter-temporal problem of saving and technological choices. After choosing technology in the beginning of a period, an agent observes the productivity of her capital in the next period and then allocates her income between consumption and saving. In formally presenting this dynamic programing problem we denote by k_{t+1}^i an agent's i capital in period $t+1$ (which equals her saving in period t) and by $V_k^{i,m}$ the value functions for an agent of cohort $k = 1, 2, 3$ (a newly born, young adult and elderly respectively) for a given a technological choices ($J_{k,t}^i$) by agent i of cohort k at time t. Recall that the capital productivity of each of the young adults and elders differ due to agent-specific past outcomes. For simplicity, however, we present the optimization problem of an agent i of cohort k at time t.These problems are (using superscript m to denote a market economy):

$$V_{1,t}^{i,m}\left(A_t^i, k_t^i \middle|\ J_{1,t}^i\right) = \max_{k_{t+1}} u^y\left(\pi_t\left(A_t^i, k_t^i, r\right) - \left(k_{t+1}^i - (1-\delta)\, k_t^i\right)\right) + \beta\lambda E_{A_{t+1}|A_t} V_{2,t+1}^{i,m}\left(A_{t+1}^i, k_{t+1}^i \middle|\ J_{2,t+}^i$$

$$V_{2,t}^{i,m}\left(A_t^i, k_t^i \middle|\ J_t^i\right) = \max_{k_{t+1}} u^y\left(rA_t^i k_t^i - \left(k_{t+1}^i - (1-\delta)\, k_t^i\right)\right) + \beta\lambda E_{A_{t+1}|A_t} V_{3,t+1}^{i,m}\left(A_{t+1}^i, k_{t+1}^i \middle|\ J_{3,t+1}^i\right)$$

$$V_{3,t}^{i,m}\left(A_t^i, k_t^i \middle|\ J_t^i\right) = \max_{k_{t+1}} u^o\left(rA_t^i k_t^i - \left(k_{t+1}^i - (1-\delta)\, k_t^i\right)\right) + \beta\lambda E_{A_{t+1}|A_t} V_{3,t+1}^{i,m}\left(A_{t+1}^i, k_{t+1}^i \middle|\ J_{3,t+1}^i\right)$$

Comparing the expected utility under various technological choices yields the optimal per-period technological choice for an agent of a given cohort and wealth which we denote by $J_{1,t}^{i,m}, J_{2,t}^{i,m}, J_{3,t}^{i,m}$ for a newly born, young adult and elderly respectively at time t.

$$\begin{aligned}
J_{1,t}^{i,m}(A_t^i, k_t^i) &= \arg\max\left\{V_{1,t}^{i,m}\left(A_t^i, k_t^i \middle|\ LR\right), V_{1,t}^{i,m}\left(A_t^i, k_t^i \middle|\ HR\right)\right\} \\
J_{2,t}^{i,m}(A_t^i, k_t^i) &= \arg\max\left\{V_{2,t}^{i,m}\left(A_t^i, k_t^i \middle|\ LR\right), V_{2,t}^{i,m}\left(A_t^i, k_t^i \middle|\ HR\right)\right\} \\
J_{1,t}^{i,m}(A_t^i, k_t^i) &= \arg\max\left\{V_{3,t}^{i,m}\left(A_t^i, k_t^i \middle|\ LR\right), V_{3,t}^{i,m}\left(A_t^i, k_t^i \middle|\ HR\right)\right\}
\end{aligned}$$

In this economy, a transition to a modern economy in which all agents use the HR technology can transpire. Declining relative risk aversion implies that sufficiently poor agents (those with low $A_t^i k_t^i$) adopt the LR technology while sufficiently wealthy agents adopt the HR technology. If there are initially sufficiently many poor agents, the average productivity of capital is sufficiently low to make the LR technology optimal for subsequent generations as well. If, however, there are initially sufficiently many wealthy agents who adopt the HR technology, their choice has a positive inter-temporal spill-over effect; it increases the initial capital productivity of the newly born. This process of higher capital productivity reinforces itself and eventually every agent employs the risky technology. Our model thereby captures that technological choices have an external effect on productivity growth and either LR or HR technologies can perpetuate in equilibrium.[24]

The HR technology Pareto dominates the LR technology because shocks are agent's specific and there is no aggregate uncertainty.[25] It is Pareto optimal for all agents to use the HR technology and share the output thereby gaining from its positive inter-temporal spill-over effects. Risk-sharing institutions can therefore determine whether an economy remains in a LR technology equilibrium or exhibits an industrial revolution, a transition to HR technology equilibrium. In our model, unlike the common Industrial Revolution macroeconomic models, societies can remain trapped in a low-growth equilibrium in the absence of risk-sharing institutions. If a risk-sharing institution is introduced, however, a larger fraction of the agents adopt the HR technology. The increase in wealth can reinforce the adoption of the risky technology, up to the point where every agent utilizes the HR technology.

3.2.2 State-based insurance: the Old Poor Law

In modeling the Poor Law, one has to consider possible distortions due to its fiscal implications. Relief to the poor has to be financed through taxation that can distort technological choices and the allocations of capital and labor. The Old Poor Law, however, was financed by a tax on land. Taxing a fixed factor acted as a quasi lump-sum tax, and it is therefore reasonable

[24] This is similar to the increasing returns to scale literature where higher income per capita leads to higher productivity levels, which itself increases income per capita and reinforces growth (e.g., Romer 1986).

[25] For a proof see Kocherlakota (1996) or Ligon, Tomas and Worral (2000). Since the endowment is state invariant in the economy and there is perfect risk sharing, agents will have constant consumption across states. Since total endowment is larger under the high risk-high return technology, agents will have a higher state-invariant consumption under the latter technology.

that distortions were relatively small.[26] Similarly, those who paid or administered the tax had neither legal nor customary rights to influence others' technological choices. Accordingly, we ignore the issue of financing (and its distortionary effect)to more clearly capture the Poor Law's impact on risk-taking rather than wealth redistribution. Specifically, we assume that the Poor Law reduces the variance of the technological shocks.[27] Accordingly, denote the standard deviation of the individual level idiosyncratic shock under the Poor Law by $\sigma^2_{j,PL}$, $j = LR, HR$ and assume that:

$$\varepsilon^{PL}_{t,j}\tilde{}F_{PL} \text{ with } \left\{F_{PL} : F_{PL}\tilde{}\left(0, \sigma^2_{j,PL}\right)\right\}$$

$$\text{with } \sigma^2_{j,PL} < \sigma^2_j$$

The Poor Law reduces risk and therefore the capital productivity levels above which agents adopt the risky technology. Formally, denote these thresholds, market, capital productivity levels by $\left(\underline{A^m_y}, \underline{A^m_o}\right)$ for the newly born and the rest of the agents respectively before the Poor Law, and by $\left(\underline{A^{PL}_y}, \underline{A^{PL}_o}\right)$ after the Poor Law. The reduction in risk implies that $\underline{A^{PL}_y} < \underline{A^m_y}$, $\underline{A^{PL}_o} < \underline{A^m_o}$.[28] (See proof in the appendix.)

By reducing the threshold levels above which agents adopt the risky technology, a Poor Law can initiate a transition that otherwise would not have happened. The simulation below lends support to the argument that the

[26] Clark (2008) estimated that the Old Poor Law was not distortive. Personal and commercial wealth was not taxed. To the extent that the Poor Law thereby led to allocating more resources toward commerce and industry, it had an additional favorable impact on industrialization.

[27] Another way to model the Poor Law is to truncate shocks below a certain threshold:

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

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

Because $E\left(\varepsilon^{PL}_{t,j}\right) > 0$ this modeling of the Poor Law implies both a change in the risk structure and wealth. To keep the introduction of the Poor Law wealth neutral, we prefer modelling as a reduction in the volatility of the shocks.

[28] It is sufficient to focus on the newly borns and the elders becuase the trashold for the young adult and the elderly are the same. The choice of the technological regime impacts next period utilty, where both the current young adults and elder agents have the same preferences.

Old Poor Law had such impact. Before turning to the simulation, however, we address the comparative question: couldn't an equivalent lineage-based insurance be similarly effective in promoting industrialization? We find that the lineage-based insurance, as practiced in China, was not similarly effective.

3.2.3 Social Insurance: The Lineage

Distinct assignment of decision rights were associated with the Chinese lineage-based institution and the English Poor Law. Under the lineage-based insurance, elders had more decision rights over technological choices than they had under the English Poor Law. The following extension of the model captures this distinction.

A lineage, Γ, is a finite group of agents of different generations that merge their endowments, share the output they produce and commonly decide which technology to use. Since each lineage has a finite number of agents, even initially identical lineages will subsequently differ in their per-period mortality and membership. We therefore model the dynamics of an average lineage, whose demographic are identical to that of the population as a whole. The average lineage is composed of one newly born, λ young adults and $\frac{\lambda^2}{1-\lambda}$ elderly agents implying an expected number of agents of $\frac{1}{1-\lambda}$.

Capital and labor are matched within the lineage and output is divided, without loss of generality, equally among members. There are $\frac{1}{1-\lambda}$ members in the average lineage and therefore each member obtains $(1-\lambda)$ of the total production. To maintain comparability with the individualistic society and to capture insurance provided by the lineage, we assume that the capital of each lineage's member is still subject to idiosyncratic shocks. The variance of the productivity shock that the lineage faces is $(1-\lambda)^2$ times smaller than the variance of any given technology. Lineages provide insurance.

Insurance provided by the lineage, everything else being equal, makes an industrial revolution more likely. Lineage-based insurance, similar to the Poor Law reduces risk and therefore the capital productivity levels above which agents adopt the risky technology. Formally, denote these threshold by $\left(\underline{A_{y,}^{\Gamma}}, \underline{A_{o}^{\Gamma}}\right)$ when there is insurance. Everything else being equal, the lineage-based insurance might be as effective in promoting risk taking as the Poor Law.

But not everything is equal. Societal organization based on lineages can also influence decision rights and in the case of China, elders had more decision rights than other members. Accordingly, we assume that the elders determine the technological choice and the capital accumulation within each lineage. Formally, the evolution of the capital stock for the average lineage is $k_{t+1}^{\Gamma} = \lambda \left(k_t^{\Gamma} (1-\delta) + h_t^{\Gamma} \right)$ where $k_t^{\Gamma} = \sum_{i \in \Gamma} k_t^i$ and h_t^{Γ} is investment at time t. The elders' decision can be analyzed sequentially first considering the optimal investment for a given the clan's members technological regime at time t , $J_t^{\Gamma} = \{LR \text{ or } HR\}$ and then considering the choice of optimal technology. Note that the value functions for the newly born and the young adults are determined by the elders' investment choice and the full insurance - equal consumption - within the clan.[29] Using the notations developed above, these value functions and choice are, for a given technology:

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

$$\begin{aligned} V_{2,t}^{i,\Gamma}\left(A_t^{\Gamma}, k_t^{\Gamma}\middle|\ J_t^{\Gamma}\right) &= u^y\left((1-\lambda)\left(\left(A_t^{\Gamma}k_t^{\Gamma}\right)^{\alpha} - \left(k_{t+1}^{\Gamma}/\lambda - k_t^{\Gamma}(1-\delta)\right)\right)\right) \\ &\quad +\beta\lambda E_{A_{t+1}|A_t} V_{3,t}^{i,\Gamma}\left(A_{t+1}^{\Gamma}, k_{t+1}^{\Gamma}\middle|\ J_{t+1}^{\Gamma}\right) \end{aligned} \tag{2}$$

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

The lineage's optimal technology is the one optimal to the elders implying that the technological regime, $J_{3,t}^{i,\Gamma}$, is:

$$J_{3,t}^{i,\Gamma} = \arg\max \left\{ V_{3,t}^{i,\Gamma}\left(A_t^{\Gamma}, k_t^{\Gamma}\middle|\ LR\right), V_{3,t}^{i,\Gamma}\left(A_t^{\Gamma}, k_t^{\Gamma}\middle|\ HR\right) \right\} \tag{4}$$

Since the elders are more risk averse than the young, it is theoretically possible that the elders would choose the LR technology in situations in which the newly born agents would have chosen the HR technology. This is likely to be the case in 'intermediate' level of capital productivity. (See appendix.) Two opposite forces emerge in the lineage-based society. On the one hand,

[29] All elders will make the same choice given that each considers the clan's total effective capital.

insurance within the lineage fosters idiosyncratic risk taking. On the other hand, the elders' higher risk aversion can imply less risk taking. Which force would dominate and whether the lineage-based insurance promotes growth more than a poor law is an empirical matter.

4 Simulation[30]

In the absence of data to conduct to an empirical analysis, we resort to simulation. Was the reduction in risk-taking caused by differences in decision rights large? More generally, could differences in risk-taking account for England's transition and China's stagnation? Our simulation suggests a positive answer to both questions.

To make the simulation meaningful, it assumes that in both societies there are initially some agents for whom the LR technology is optimal. This allows for an absorbent steady state where income per capita is relatively constant over time. The simulation then examines the differential impact of state-based and lineage-based risk-sharing institutions assuming that both institutions provide the same level of risk-sharing. The simulation thus reveals the impact of the difference in risk-taking these institutions entail.

4.1 Parameter Choice

In the model there are parameters related to preferences and technology. The main parameters that affect preferences includes risk aversion (σ) and discounting ($\lambda\beta$). The main parameters that affect technology are means (μ_{LR}, μ_{HR}), variances (ν_{LR}, ν_{HR}), capital share (α) and depreciation rate (δ).

We use a CES utility function and to prevent uninsured agents from always preferring the risky technology, we set the common risk aversion parameter, σ, to 5. (Such value is high within the range of risk aversion coefficients in the macroeconomics literature.) To make elderly agents more risk averse and generate the DRRA property, we introduce different minimum consumption requirements for the young and the old.[31] Specifically,

[30] This simulation is tentative and based on a slightly different specification of the newly born profit function. We are in the process of rerunning the simulation and expect the results to be qualitatively the same.

[31] This property enables us to carry our argument that higher wealth induce agents to

the utility function of agent u^r, $r = y, o$ is:

$$u^r = \frac{(c - \overline{c}^r)^{1-\sigma} - 1}{1 - \sigma}$$

where $\overline{c}^y < \overline{c}^o$. The relative risk aversion coefficient R^r is:

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

This specification leads to a reasonable difference in risk aversion between the young and the old. Assume that the consumption requirement for the young is $\overline{c}^y = 0.01$ and for the old is $\overline{c}^o = 0.05$.[32] We set the interest rate r to 4.5% a year (yielding a 141.17% return every twenty year period), so that the steady state consumption per capita is the same across societies before the poor law is established and therefore the relative risk aversion profiles. Given that consumption per capita in the simulation is almost 0.55, the risk aversion coefficient for the young initially becomes 5.09 and 5.5 for the elderly, that is, 8% larger.

Each period lasts for twenty years in our simulation. Agents are newly born in the 0-19 cohort, young adult in the 20-39 cohort and elderly for the rest of the cohorts. We set the discount factor, β, to .603, which implies an annual discount factor of .975. Agents die with a per-period probability, λ,of .5. An agent's expected working life is thirty years which is reasonable given that as late as the early 19th century, life expectancy at birth was about 40 years.[33] We assume that young agents are born with the average productivity of the previous period and the average capital level of the previous period minus depreciation.

The LR technology has a return $\mu_{LR} = 0$, while the HR technology has a period return of μ_{HR} = 10.489% which implies a 0.5% return a year.

engage in further risk, for lotteries that affect capital productivity in absolute value and in percentage change.

[32] We set the initial capital stock and capital productivity values to generate a steady state where none of the agents ' consumption goes below 0.01 when young and 0.05 when old, and to prevent A_t^i from becoming negative.

[33] In the early nineteenth century China (the Yangzi Delta), male life expectancy at 15 was between 30 to 54 years (Liu, Cuirong, 1992 cited by Brenner and Isett, 2002). In our model the probability of being older than 100 years 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.

Although this return is low, it corresponds to England's history. In the early stages of the Industrial Revolution (1780 to 1820), the annual income per capita growth rate was slightly less than 0.5% (Maddison 1991).

To simplify the simulation we set the binomial shock, ε_t^i, to $\varepsilon_{t,LR} = \pm\nu_{LR}$ and $\varepsilon_{t,HR} = \pm\nu_{HR}$ for the low and high risk technology respectively. Table 1 shows the level of ν_{LR} and the relative value of ν_{HR} on the rows and columns respectively, given that the rate of return for the LR and HR technologies are 0 and 0.5% a year respectively. We set the absolute and relative size of the variances to replicate the initial conditions of zero or very low productivity growth. If the shocks are too small, the initial capital and productivity endowments determine whether all or none of the agents engage in risky activities. Larger values for ν_{LR} enable more technological transitions as positive productivity shocks imply that the optimal technology from LR to HR. Under the Poor Law, large shocks enable us to have agents switching from low income levels to income levels that are high enough to adopt the HR technology. Once agents choose the HR technology they might transition back into the less risky technology. However, given the higher mean, this transition is less likely to happen. If ν_{LR} is below 0.1, there is almost no transitions. On the other hand, if ν_{LR} is above 1/3, there is too much variation in the shocks and we have cases were productivity becomes negative for some agents. If ν_{HR} is twice as much as ν_{LR}, too many people engage in risky activities. If it is three times as much, only some individuals engage in risky activities in the steady state before the Poor Law is introduced. If it is four times as much, almost no individuals engage in the risky technology. We let ν_{HR} be three times as high as ν_{LR} and set $\nu_{HR} = 1$ and $\nu_{LR} = 1/3$.

The survival probability of 1/2 implies that there are two agents in the average lineage, meaning that the shock it faces is four times smaller than the one any given individual faces in the English society. We therefore model the lineage shock to be half as large: $\varepsilon_{t,j}^{\Gamma} = \frac{\varepsilon_{t,j}}{2}$. We consider the Poor Law as a reduction in volatility. We reduce the shock to the lineage value, that is one half, and let the English agents face the same shocks that the Chinese lineage faces. By reducing the shock by half, we assume the Poor Law provides the same social insurance that the lineage does (recall that the average lineage is composed of two members).[34]

Since ν is fixed, the wealthier the individuals are, the more they are

[34] We have performed a comparative statics analysis where we increase the number of agents per lineage. The more agents present in the lineage, the more inclined the lineage is to engage in the risky technology. This matches the anecdotal evidence of the Tong and

inclined to engage in the risky technology. We have also modeled the case where the shock is heteroskedastic and takes the form: $\varepsilon_t = \pm\nu * A_t$. Since preferences are DRRA, as agents become wealthier the same effect emerges as in the fixed case and the results we obtain are similar to the ones reported.

We set the capital share $\alpha = 1/3$, the depreciation rate $\delta = .543$, implying a 3% annual depreciation and a population size of 10000. Table 2 summarizes the parameters chosen for the simulation.

4.2 Results

The simulation supports the conjecture that risk-sharing institutions might have been important in England's transition and China's relative lack of economic growth. In China, the lineage provides risk-sharing and although the risk averse elders chose technology, a small fraction of the lineages takes risk. If the fraction is sufficiently small, however, there is no transition. There is no major shift toward using the HR technology. In England, prior to the Poor Law, there is no risk taking at all and the economy is literally stagnant. Once the Poor Law is established, the thresholds to engage in riskier activities are reduced and there is an instantaneous spike in the fraction of the population that engages in such activities. This immediately generates income per capita growth that fosters further risk taking. A transition transpires until every agent uses the HR technology and consumption per capita growth becomes positive.

Initially, all elders in England prefer the low return technology while sufficiently wealthy young adults would choose the risky technology. Once the Poor Law is established the thresholds are reduced for both types. Elderly agents engage in risky activities if productivity and their capital stocks are sufficiently high, and young adult do so for a larger state space than they did before. Figure 1 and 2 show the regions of A_t and k_t for which the newly born and elderly respectively choose the different technologies. The black area represents the adoption of the LR technology while the shaded area represents the adoption of the HR technology.

Prior to simulating the introduction of the Poor Law in England, the English young adults are less risk takers than China's elders. In other words, the elders in China have a lower productivity threshold above which they take risk than the English young adult. The effect of the risk-sharing provided

Song dinasties, where lineages were widely extended as well as economic prosperity.

by the lineage is stronger than the effect of the elders' higher risk aversion. Once the Poor Law is passed, the thresholds for the English young adult and elders are lower than those of the Chinese elders. Figure 3 shows the regions of A_t and k_t for which a lineage's elders choose each technological regime. Again, the black area represents the LR technology while the shaded area represents the HR one.

Figure 4 shows the evolution of consumption per capita over time under the two social arrangements. The grey vertical line represents the introduction of the Poor Law, which we denote as period 0. Consumption per capita is immediately reduced after the Poor Law is introduced, as agents decide to engage in riskier activities and increase their precautionary savings (capital) in case they receive a large negative shock. Afterwards, consumption per capita grows at a positive rate forever, eventually surpassing the Chinese levels.

The fraction of the population that engages in risky activities is relatively constant in the lineage society and close to 18%. England has no population engaging in such activities and once the Poor Law is established, it increases immediately to 30%. This positively impacts income per capita and reinforces itself, up to the point where every agent in the population chooses the HR technology. In the meantime and also all throughout the Chinese experiment, there is substantial reallocation of agents, moving back and forth from the LR to the HR regime. Depending on the state variables, agents shuffle from one technology to the other. Even when England becomes wealthier over time (and more agents engage in riskier technologies), there is still a lot of reallocation depending on the particular idiosyncratic shocks that each of them faces. Figure 5 shows the evolution of the fraction that engages in risky activities over time.[35]

The accumulation of capital is constant in China throughout time and in England before the Poor Law. After the Poor Law, there is a rapid capital accumulation that is partly (although definitely not fully) reversed immediately after. This spike reflects two effects: a larger expected capital productivity value for next period and precautionary savings. Initially, agents are still poor and hence relatively more risk averse. They accumulate extra capital to mitigate the increase in risk. As time goes by and agents become wealthier,

[35] After the Poor Law is established, many agents are left very close to the technology choice thresholds and therefore idiosyncratic shocks do alter their choices. Even with a 10000 agents simulation we still obtain a slightly volatile series which trends upwards after the poor law is established.

the second motive vanishes and capital accumulation decreases slightly.

We have also evaluated whether the simulation captures the essence of our model by simulating the introduction of a Poor Law in China and the impact of larger clans. Our theory predicts either Poor Law or larger clans could have led China to industrialize by providing more insurance. The simulation confirms these predictions. Once a Poor Law is introduced in a lineage society, agents adopt the risky activities and the growth rate of consumption per capita becomes positive. Similarly, increasing clans' size by more than three times, leads all agents to adopt the HR technology.

Evaluating why a Poor Law was not introduced or clans did not increase in size is beyond the scope of this paper. Yet, the Poor Law may not have been introduced because a universal, compulsory law would have undermined the lineage system through which the state was administered. Similarly, the decline in communal families indicates that moral hazard and adverse selection problems limited the size of clans.

5 Supporting Historical Observations

The comparative technological history of China and England presents a puzzling observation. China which was ahead of England, fell behind. During the Song dynasty (960-1279), 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). Yet, shortly after the fall of the Song, technological development slowed and China became, relatively speaking, technologically stagnant (ibid, p. 219). England, in contrast, leaped ahead. This reversal of fortune is inconsistent with existing endogenous growth models. Similarly, there are historical analyses of why either China declined or England advanced, but no analysis explains both time trends. Our conjecture is consistent with both.

Consider first China. We argue that two factors determined the impact of its lineage-based institutions on growth. Intra-lineage insurance encouraged risk-taking while control by the risk-averse elders discouraged risk-taking. This implies more (less) technological progress when lineages provides more (less) insurance and when elders are less (more) powerful. Consistent with these predictions, during the Song, kin provided more insurance than later through communal families while the later lineages provided only poor relief (and see subsection 2.3). Elders also had less legal authority during the Song dynasty than later. Under the Song, a parent who killed an unfilial son was subject to a lower punishment compared to other murders. As severe this law may seem, 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.

Finally, the Song was the only post-1000 dynasty to have a substantial state-based, risk-sharing institutions. Wang Anshi, a prominent Song minister and reformer asserted that the state was responsible for providing the poor. Under his direction the state instituted pensions for the needy. (Ebrey, Walthall, and Palais 2005). Later dynasties, did not follow this example although because clans were mainly rural, poor relief was sometimes provided in cities.

When the Song ruled China, England was less innovative but during the seventeenth century, its economy began the expansion leading to the industrial revolution. Our analysis suggests an explanation. While China had effective risk-sharing institutions long before the seventeenth century, England did not (Solar 1995, p. 8). England lagged in the absence of comparable risk-sharing institutions. Following the introduction of the Poor Law 1601, however, England leaped ahead. England economic ascendancy began by the mid seventeenth century (Nef 1940; Clark 2005).

A similarly puzzling observation is that during the Industrial Revolution, England was not particularly inventive. It was particularly good in adopting, adapting, and commercializing inventions made elsewhere. France was a particularly important source of inventions (Mokyr 1990). This observation is consistent with our conjecture. England's risk-sharing institutions did not specifically rewarded inventors and its patent system was not particularly rewarding either (e.g., Khan 2008). The Poor Law encouraged risk-taking in commercializing inventions by securing local landlords and industrialists from the social unrest that their innovative activities might have otherwise caused. France, which did not have a patent system during that period, was nevertheless inventive because inventors were rewarded by the Crown (Kremer 1998). France's Poor Law system, however, was not as effective as England's (e.g., Solar 1995, p. 7; Lindert 2004, p. 8) and innovations did not follow inventions.

Despite the differences between England and other European states, these states were in a better position to imitate England. In contrast to China they did not have lineages, had a legal, social, and cultural organization that did not favor the elders, had an experience in state-based poor relief. As our analysis predicts, Europe industrialized relatively quickly after England while China did not. Notably, the continental industrialization transpired in the context of creating the modern, state-based welfare system. (Lindert 2004). At this point in the process of the rise of the modern economies, formal education became more important as a source of productivity growth (Easterlin 1981).

6 Conclusion

Growth theory faces the challenge of explaining the initial increase in the rate of productivity growth that causes transitions to modern economy. Initial transitions are due to either favorable realizations of random variables or a technological drift. This paper presents how institutional, and therefore technologically feasible, changes can influence choices generating new knowledge and leading to productivity growth. It demonstrates the theoretical possibility that the rate of technological change is endogenous to risk-sharing institutions. Different risk-sharing institutions imply distinct rates of technological changes.

Our analysis focuses 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 risk-sharing was provided by elders-dominated kinship groups, a transition to a modern economy 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 a transition. Our simulation demonstrates that the Poor Law – which provided better insurance in individualistic England – may have had an important role in its transition to a modern economy.

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, for example, 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).

Ironically, Europe's success might not have been due to foresight but an unintended consequence of its peculiar institutions. The Poor Law was not designed with an economic transition in mind. It was aimed at, and was effective in, governing a transaction between the wealthy and the poor in which the former provided economic support and the latter refrained from disturbing the peace. The institution had, however, unintended consequences on behavior in other transactions. Specifically, transactions related to risk-taking and the creation of new knowledge.

More generally, the analysis reaffirms that in considering the origin, nature, and implication of economic institutions it is important to study them from a broader perspective. One that recognizes that institutional development is a historical process in which economic social, cultural, and political factors matter and unintended consequences can be as important as intended ones (Greif 1994, 2006, 2007). In this work, modeling different risk-sharing institutions as shift parameters influencing the extent of risk-sharing would not have been sufficient to identify their implications. To capture these implications it was necessary to identify the context and their details and to integrate these in a macroeconomic benchmark model. Enriching unified growth theory by incorporating institutions utilizing this broader perspective has the promise to further enhance our understanding of the "change in human condition that the industrial revolution represents" (Lucas 2002, p. 110).

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8

9 Appendix: Productivity Level and Optimal Technology

Remark 1 *For every state of the world and social arrangement (* $r = m, PL,$ *or* Γ*) there is a pair of productivity levels* $\left\{\underline{A_y^r}, \underline{A_o^r}\right\}$ *such that if* $A_t < \underline{A_y^r}$*, LR technology is optimal for all agents; if* $A_t \in \left[\underline{A_y^r}, \underline{A_o^r}\right]$*, the HR (LR) is optimal for the newly born (young adult and older agents); and if* $A_t > \underline{A_o^r}$*, HR technology is optimal for all agents.*

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

$$sign\ E_{A_{t+1}|A_t} V_2^r \left(A_{t+1}, k_{t+1} \middle| \ (A_t, k_t)\,,\ HR \right) - E_{A_{t+1}|A_t} V_2^r \left(A_{t+1}, k_{t+1} \middle| \ (A_t, k_t)\,,\ LR \right) \tag{5}$$

$$\text{for } r = m, PL, \text{ or } \Gamma$$

The young adult and the older agents always have the same optimal technology. The choice of technology impacts on next period utility, where both types of agents will have the same (elderly type) preferences. Their decision depends on:

$$sign\ E_{A_{t+1}|A_t} V_3^r \left(A_{t+1}, k_{t+1} \middle| \ (A_t, k_t)\,,\ HR \right) - E_{A_{t+1}|A_t} V_3^r \left(A_{t+1}, k_{t+1} \middle| \ (A_t, k_t)\,,\ LR \right) \tag{6}$$

$$\text{for } r = m, PL \text{ or } \Gamma$$

Since all the agents have DRRA utility functions, given the state variables (A_t, k_t), there is a threshold productivity value, $\left\{\underline{A_y^r}, \underline{A_o^r}\right\}$ for (5) and (6) 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 in each of the social structure organizations. Since elderly agents are more risk averse than young agents (5) is always higher than (6) and therefore $\underline{A_y^r} < \underline{A_o^r}$. This determines three zones. Given (A_t, k_t), if $A_t < \underline{A_y^r}$, there is unanimity and all the agents favor the low risk-low return regime. If $A_t \in \left[\underline{A_y^r}, \underline{A_o^r}\right]$ newly born favor the high return regime while the rest of the agents the low return regime. If $A_t > \underline{A_o^r}$, all the preferences are realigned again and everybody favors the high return regime.

■

10 Tables and Figures

Figure 1. Technological Choice for the Newly Born Market Society

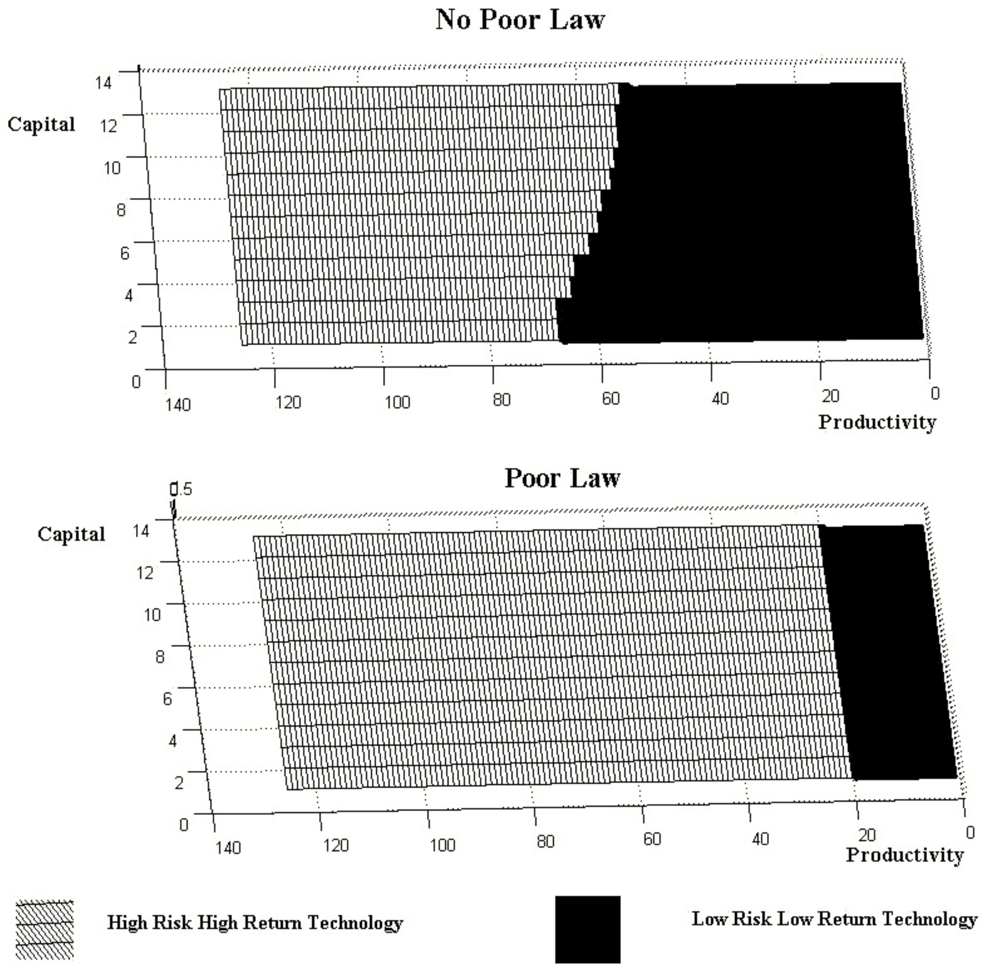

Figure 2. Technological Choice for the Elderly Individualistic Society

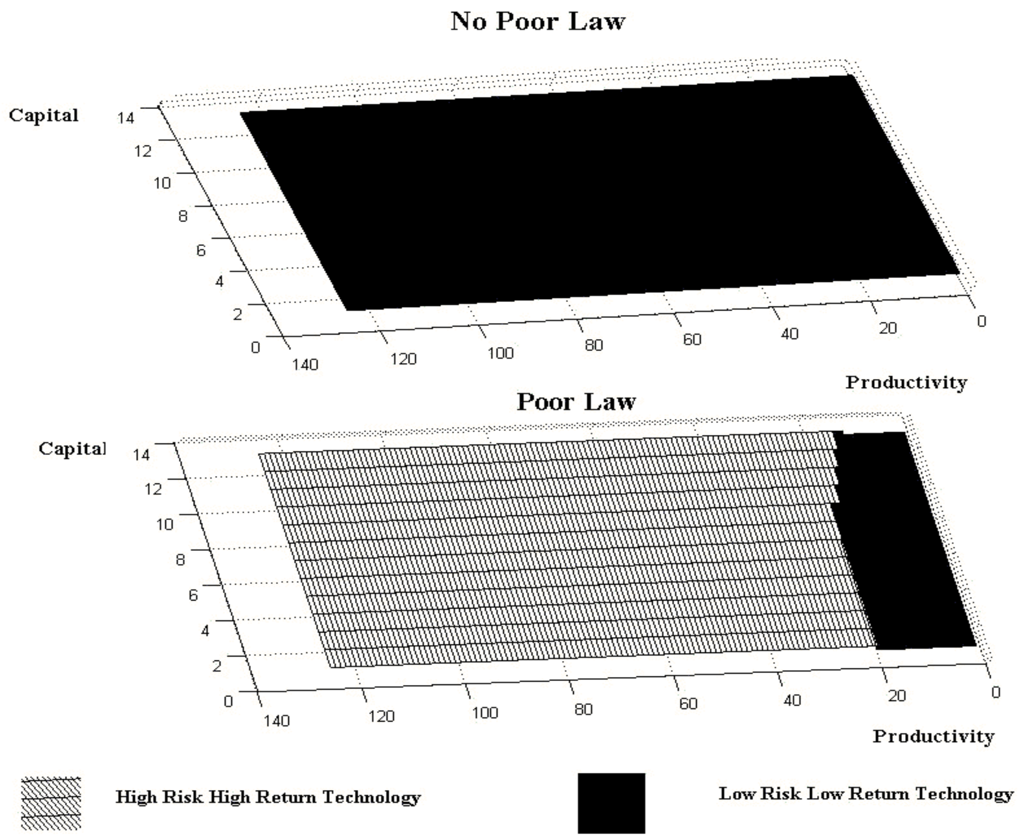

Figure 3. Technological Choice
Lineage Society

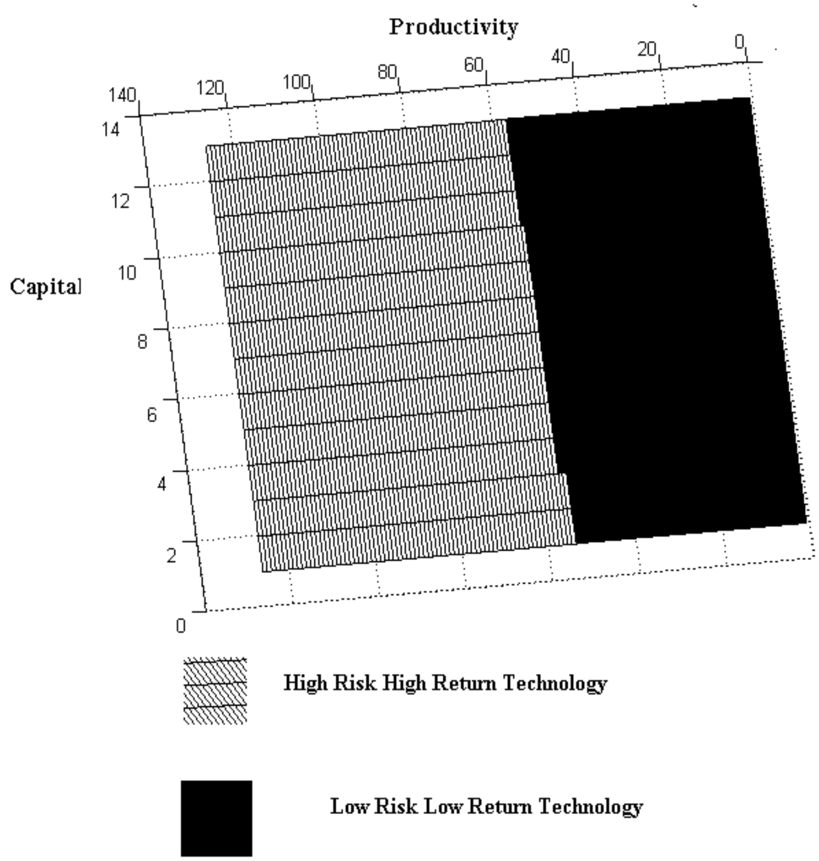

Figure 4. Consumption per Capita

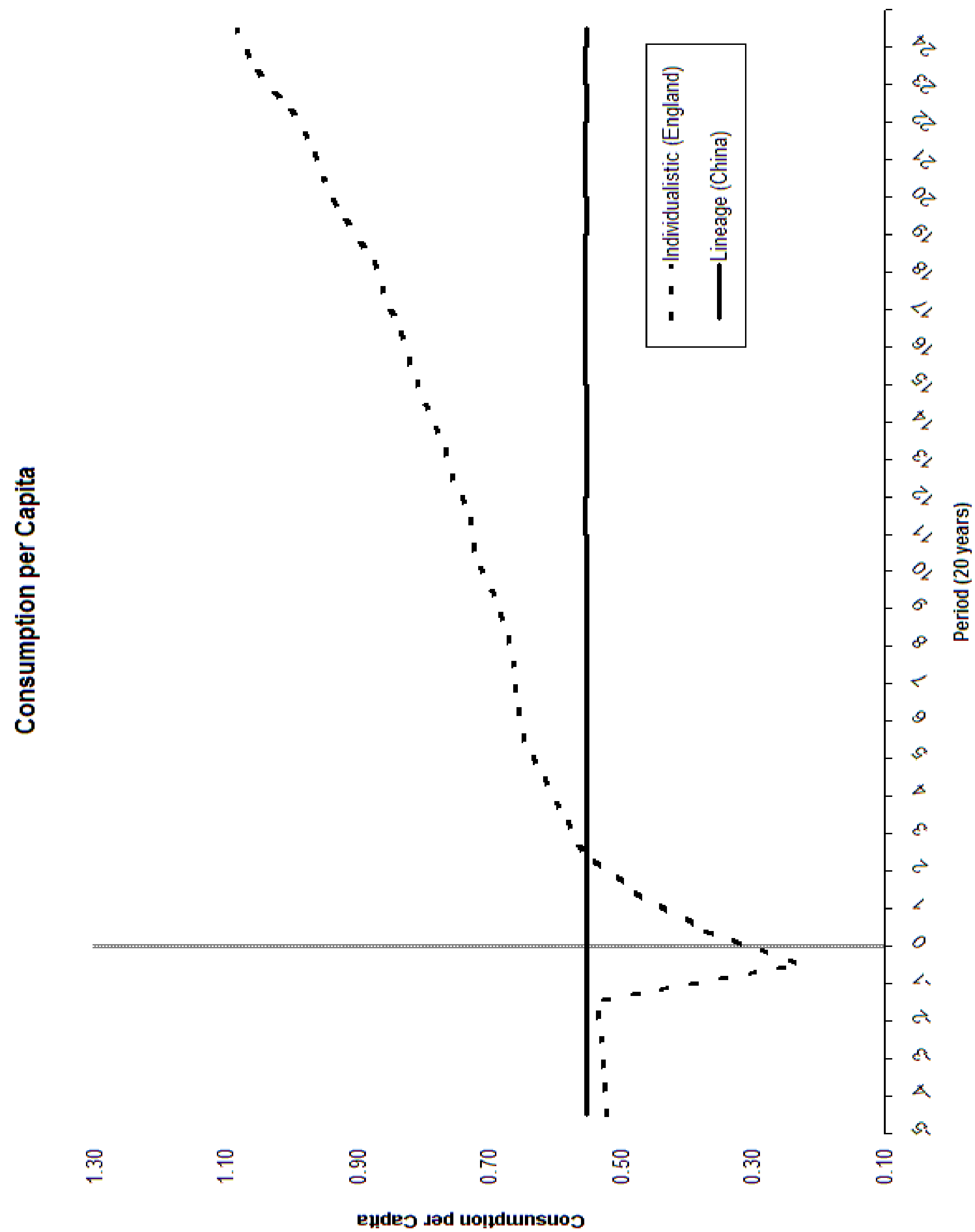

Figure 5. Fraction Engaging in Risky Activities

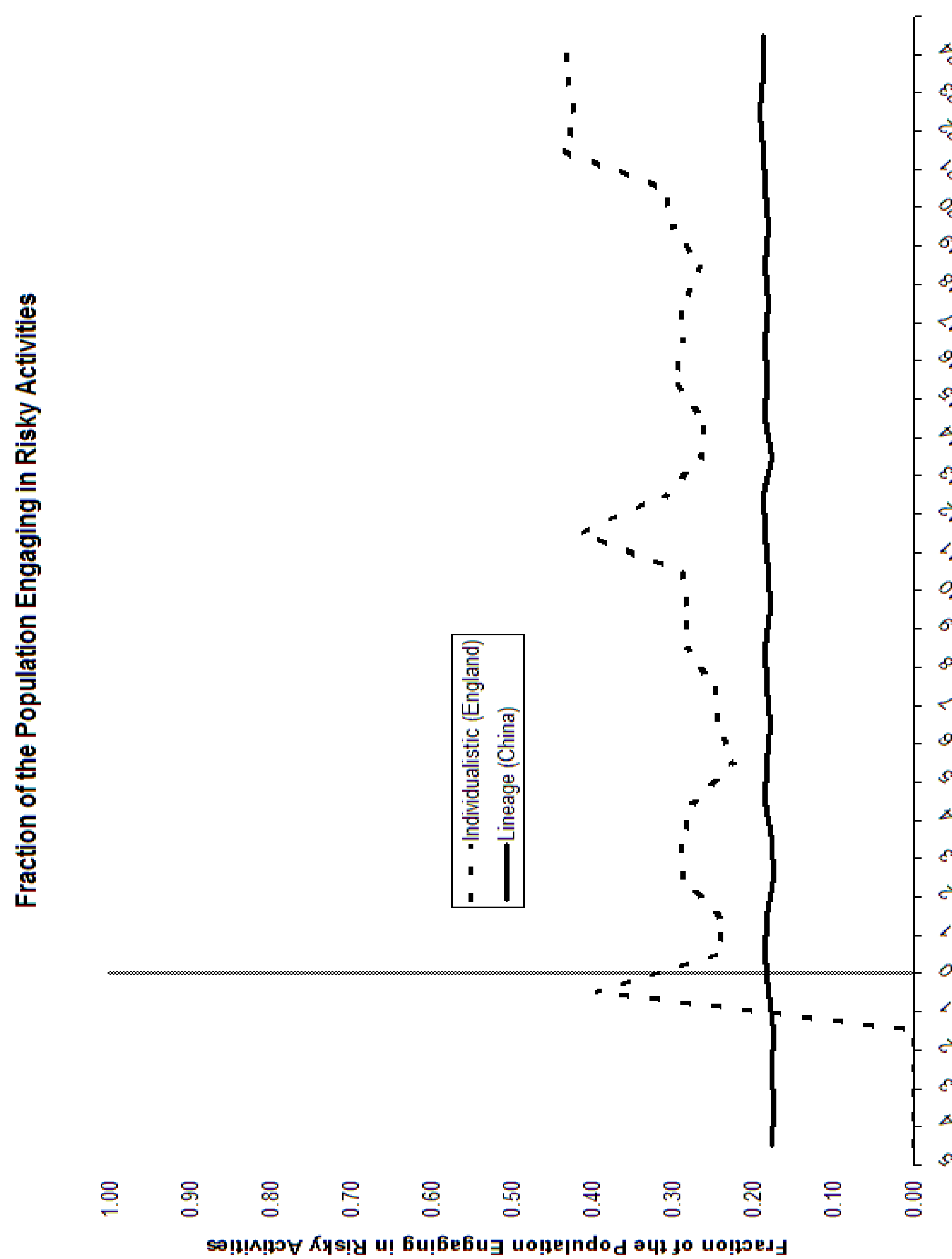

Figure 6. Capital Accumulation

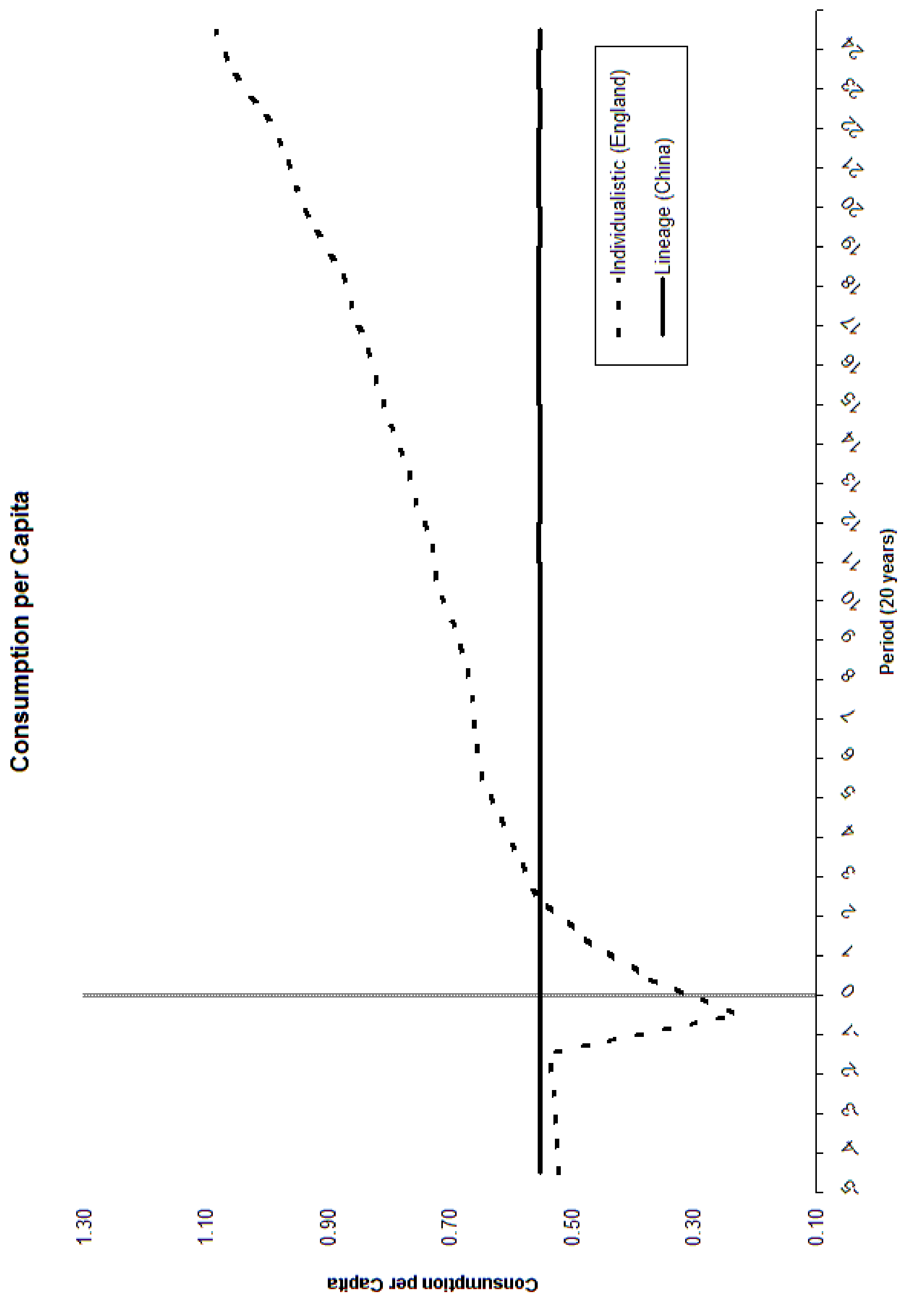

Table 1. Idiosyncratic Shocks

$v_{LR} \backslash v_{HR}$	$v_{HR} = 2 * v_{LR}$	$v_{HR} = 3 * v_{LR}$	$v_{HR} = 4 * v_{LR}$
$v_{LR} = 0.01$	HR, No Transition	HR-LW, No Transition	LR, No Transition
$v_{LR} = 0.05$	HR, No Transition	HR-LR, No Transition	LR, No Transition
$v_{LR} = 0.1$	HR, No Transition	HR-LR, No Transition	LR, No Transition
$v_{LR} = 0.33$	HR, Transition	HR-LR, Transition	LR, Transition
$v_{LR} = 0.5$	HR, Transition	HR-LR, Transition	LR, Transition

Table 2. Parameters

c_y	c_o	σ	β	λ	μ_1	μ_2	ν_{LR}	ν_{HR}	δ	r	α
.01	.05	5	$.975^{20}$	1/2	0	$1.005^{20} - 1$	1/3	1	$(1 - .03)^{20}$	$1.045^{20} - 1$	1/3