How the West Invented Fertility Restriction*

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Abstract

Early modern Europe was unusually rich by 1700, compared to the rest of the world. We argue that the 'European Marriage Pattern' (EMP) contributed to this phenomenon. By raising the marriage age of women, and ensuring that a substantial proportion remained celibate, EMP reduced fertility by up to 40%, and raised average wages by a quarter. We present a model that explains how fertility limitation evolved. We emphasize changes in the production structure of the agricultural sector – from labor-intensive grain production to land-intensive pastoral production of wool, milk, and meat. Following the 14th century Black Death, increased land-labor ratios rendered pastoral agriculture feasible. While more land-using, this type of production was also less physical labor intensive than crop growing, giving women a comparative advantage in this sector. Following this introduction of female employment opportunities, a period of working as a servant became a common feature of the life cycle of European women. Marriage was thus delayed, and fertility reduced, which decreased population pressure in a Malthusian setup. The Black Death set into motion a virtuous circle of higher wages and fertility decline that enabled Europe to maintain unusually high per capita incomes.

1 Introduction

Fertility decline is a key feature of the transition to self-sustaining growth. A large literature in economics tries to explain why fertility fell at the same time as incomes began to grow after 1850, emphasizing the growing importance of child quality (Barro and Becker, 1989) or cultural factors associated with the demographic transition (Princeton Fertility Project). What is not well-understood is how fertility became a choice variable at all. Long before the advent of modern growth, Europeans restricted their fertility. Since medieval times, in an area West of a line from St Petersburg to Trieste, the age of marriage for women was not determined by biological fertility, but by socio-economic forces (Hajnal, 1965).[1] Both the marriage age and the proportion of women never marrying varied in response to economic conditions. The so-called 'European Marriage Pattern' (EMP) combined late marriage with unrestricted fertility within marriage. It also constitutes a puzzle. Given that there were few births outside marriage, and that knowledge of contraceptive techniques was limited, EMP required a large share of the female population never to engage in sexual activity; for the rest, abstinence until their twenties was necessary. Effectively, Europeans traded off higher living standards - more goods, and more food - for less sex, and fewer offspring.

EMP contributed to higher incomes. By 1700, European output per head was far above subsistence, and markedly ahead of output in the rest of the world (Maddison, 2001; Broadberry and Gupta, 2005).[2] Even without rapid technological change, an early modern 'first divergence' preceded the large income differences that evolved after 1800. The European Marriage Pattern contributed to the 'first divergence' by keeping European land/labor ratios higher than they otherwise would have been. On average, between a quarter and 40% of all possible births were avoided (Clark, 2007). Since land was in fixed supply, fertility restriction paid in terms of higher incomes. EMP also acted as a "shock absorber" – fertility restriction became more stringent as times became harder. Kelly (2005) shows that negative shocks to output as a result of adverse weather led to lower fertility. This helped to stabilize per capita output. While there is agreement that EMP was a unique social institution with a large economic impact, there is no widely accepted interpretation of its emergence.

In this paper, we develop a simple Malthusian model with two sectors of agricultural production to explain the rise of fertility restriction in Western Europe. Each sector produces a single good - grain and 'horn' (pastoral products). Grain production is performed by males only, while both sexes can work in horn production. Both sectors use land as an input, but pastoral farm uses land more intensively. The economy is Malthusian in nature. A negative shock to population raises land-labor ratios. The horn technology now operates. Women begin to work, and fertility declines. While the economy does not lose its Malthusian

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[1] The pattern was later found to be particularly strong in the North-West of Europe, and weaker in the South. Other areas of the world practiced fertility control in the form of infanticide; abandoning unwanted children has always existed as an option. For our purposes, the type of fertility control in need of explanation involves a voluntary decision, possibly mediated through a socio-economic institution, that avoids births.

[2] Average urbanization rates reached 10%, and in the most advanced areas, rates were even higher. China, on the other hand, saw stagnation at a rate of 3% (Maddison, 2001). A group of revisionist historians has questioned the traditional consensus that labor productivity in Chinese agriculture was low (Li, 1998; Pomeranz, 2000; Goldstone, 2003). Pomeranz in particular has argued that incomes in the Yangtze were comparable to English ones. Their analysis has not stood up to close scrutiny (Brenner and Isett, 2002; Broadberry and Gupta, 2005).

characteristics, income gains become sustainable because low fertility keeps land-labor ratios high – the economy transitions to a new equilibrium with a higher per capita income. In addition, the new regime helps to stabilize incomes. If productivity is temporarily lower such that income falls, the marginal utility of consumption increases, driving women to work in pastoral agriculture. With female labor supply surging, fertility falls, which cushions the impact of negative productivity shocks. Thus, incomes are more stable than they would be without fertility restriction.

The trigger for the change to a low-fertility regime in our model is the Black Death. It killed between a third and half of the European population. As the number of workers fell, land/labor ratios surged. Wages were high, and food was plentiful. For a period of one-and-a-half centuries, Europeans experienced a 'golden age of labor.'[3] According to the Malthusian model, this rise should be temporary. As population recovered, incomes ought to fall until they reach the pre-plague level. Yet as late as the 17th and 18th centuries, per capita output in Northwestern Europe remained 35-50% higher than it had been on the eve of the Black Death (Maddison, 2007).[4]

Female labor became more valuable after the Black Death in 1348-50 because higher wages raised meat, dairy, and wool consumption. By 1516, when Sir Thomas More described 'man-eating sheep' in his *Utopia*, vast parts of English agricultural land had been converted to sheep pasture.[5] Sheep grazing and cattle raising were land-using and labor-saving. Many laborers could be replaced by a single shepherd or servant in husbandry. At a time of high wages and abundant land, pastoral farming was a profitable mode of production. Production was subject to some minimum size constraints - farms had to be big enough to support life-stock. It also used labor that was relatively cheaper: children and women.[6]

By creating a demand for women's labor, expanded pastoral production enhanced female employment prospects. It did so through an institution that also curtailed female fertility. Since women caring for children are generally unsuited for field work with animals, this mode of production also required that females working in husbandry remained unmarried. Landlords regularly took in young men and women, housed them and fed them in exchange for their labor services.[7] Of all workers employed in agriculture, between a third and half were servants. Servants constituted 13% of the English population between 1574 and 1821. While some of them worked as domestic servants, enhancing the comfort of their masters, most were employed as 'productive servants.' According to Kussmaul's (1981) calculations, approximately 60% of the population aged 15-24 worked as servants. Therefore, most early modern youth worked as servants

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[3] According to the classic long-run wage series by Phelps-Brown and Hopkins (1981), 14th century English real wages more than doubled after 1349. More recent studies also show marked increases (Clark, 2005; Apostolides, Broadberry, Campbell, Overton, and van Leeuwen, 2008).

[4] If we focus on the wages of farm workers – arguably a better indicator of agricultural output per head – English wages and output at the early modern trough (in 1600) remain roughly 50% higher than on the eve of Great Plague (Apostolides et al., 2008).

[5] This was despite repeated interventions by the Crown (in 1489 and 1514) that attempted to stop the conversion of arable lands (Rodrick, 2004).

[6] Agricultural technology in use changed in response to factor prices, not through directed search for better production techniques in the sense of Acemoglu (2002). Rather, adoption decisions in response to changing output and input prices caused a shift in the production technology employed.

[7] They would also offer them some additional monetary reward which would typically be saved for later use, once servants formed a new household (Kussmaul, 1981).

in husbandry at some point in their lives.

We are not the first to argue that the Black Death caused important changes in the European economy, and that some of them raised per capita output. Van Zanden (2002) concluded that the rapid rise of the Netherlands during the early modern period owed much to the economy's transformation after 1350. Herlihy (1997) speculated that the rise of fertility control may have been linked to the effects of population losses after the plague, and Smith (1981) suggested that the rise of farm service may have been one of the reasons for greater fertility control. Epstein (2000) argued that institutional constraints on growth were removed, Mancur-Olson-style, by the plague. Finally, Pamuk (2007) surveys the evidence that the Black Death ushered in important changes in the European economy, reducing and then reversing the income gap between Southern and Northwestern Europe.

Related work on the origins of the European Marriage Pattern includes Devolder (1999), who emphasized the introduction of short-term leaseholds as a factor behind the rise of EMP. The paper that is closest in focus to ours is de Moor and van Zanden (2005). The authors emphasize the role of Christianity, with its emphasis on the individuality of each soul and the importance of an act of the will for marriage to be valid. They also argue that the rise of a landless proletariat, combined with access to urban labor markets, militated in favor of women 'taking time to choose' their marriage partners. Because many parents were landless, they could not entice their children to stay on the land, working on the family farm in the hope of an inheritance. Thus children sought out outside earnings opportunities, especially when these were attractive in financial terms (such as after the Black Death).

Our paper forms part of a broader body of work that seeks to explain fertility change. The Princeton European Fertility Project (Coale and Watkins, 1986) argued that culture was crucial for the diffusion of fertility limitation in the 19th century.[8] Much of the work on the economic incentives for fertility restriction after 1850 has emphasized the importance of changing payoffs to investments in child quality (Barro and Becker, 1989). An alternative strand of the literature emphasizes changes in the opportunity cost of female labor (Becker, 1960; Mincer, 1963). Butz and Ward (1979) as well as Heckman and Walker (1990) find evidence that higher male wages raise fertility, while higher female wages lower them. Schultz (1985) showed that a large part of fertility decline in 19th century Sweden was driven by world demand increasing the price of butter relative to grain. Attention has also focused on the changing cost of children as a result of nineteenth-century compulsory schooling laws and factory acts restricting child labor (Doepke, 2004; Puerta, 2009). Recently, Greenwood, Seshadri, and Vandenbroucke (2005) have explored the impact of labor-saving household technology on fertility, while Doepke, Hazan, and Maoz (2007) argue that one-off negative shocks to the value of female labor can lead to large increases in fertility.[9]

Relative to this literature, we make a number of contributions. We present the first economic model in which the European Marriage Pattern arises endogenously, in response to a positive, large shock to income. Our modeling exercise is in the spirit of what has been called "Institutional and Comparative Historical

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[8]Recent work using disaggregated data for Bavaria and for France has questioned this conclusion (Brown and Guinnane, 2001; Murphy, 2006).

[9]They argue that the use of women in US wartime production during 1940-45 generated a negative externality for younger cohorts, who then engaged in more child-bearing.

Analysis" (Greif, 1998). We focus on the emergence of a new regime in which fertility is i. lower on average, and ii. responds positively to higher wages. We generate massive fertility restriction without a role for human capital, in contrast to models in the spirit of Barro and Becker (1989). Also, heterogeneity in wages or tastes plays no role in our model (Jones, Schoonbroodt, and Tertilt, 2008). Our approach emphasizes female opportunity cost, as determined by changes in the structure of agricultural production following the Black Death. We also are the first to assess quantitatively the role of EMP in the 'First Divergence,' using a calibrated model of the Malthusian economy.

The research agenda of Unified Growth Theory is also relevant to our work. It seeks a single explanation of the transition from 'Malthusian stagnation' to self-sustaining, rapid growth (Galor, 2005; Hansen and Prescott, 2002; Galor and Weil, 2000; Kremer, 1993). Papers in this tradition typically assume that as growth takes off, the return to human capital rises (Becker, Murphy, and Tamura, 1990; Lucas, 2002; Jones, 2001).[10] The unit of analysis is typically the world as a whole, not individual countries. Instead, we emphasize the potential for fertility to change substantially prior to the "take-off." We also focus on cross-sectional differences, since we seek to pin down the contribution of fertility to the "First Divergence." In our setup, the plague shock interacts with the initial productivity in grain production, as determined by land conditions and population levels before 1350. We argue that high grain productivity in China prevented the adoption of pastoral agriculture. Our theoretical setup shares some similarities with Galor and Weil (1996), where the complementarity between capital and labor is stronger for women than for men.[11]

We proceed as follows. Section II discusses the historical background and context. In section III, we present our model of fertility restriction. Next, we calibrate our model. For plausible parameter values, the same shock to land-labor ratios can lead to the adoption of very different agricultural and fertility regimes in Europe and China. Section V concludes.

2 Historical Context and Background

In this section, we discuss the historical background and context of EMP's emergence. We first summarize the available evidence about the rise of fertility limitation, and then examine the connection between nuptiality and the organization of agricultural production. Next, we summarize the existing evidence on changing consumption patterns after the Black Death. Finally, we compare European and Chinese fertility patterns and agricultural norms.

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[10]Fernandez-Villaverde (2001) presents a model in which the declining relative price of capital during the Industrial Revolution raises skill premia, and thus generates incentives to trade child quality for quantity.

[11]In their model, technological change drives the entire transition. An initial gain in capital intensity leads to fertility decline through a rise in the opportunity cost of female time. This then increases incomes, which also cause capital-deepening. In contrast to their setup, we are not trying to model a transition to self-sustaining growth. Rather, we emphasize the emergence of a new institution that underpins permanently higher incomes.

2.1 The Origins of the European Marriage Pattern

The historical origins of the 'European Marriage Pattern' cannot be determined with precision. To track its evolution, we would need detailed information on the percentage of women never marrying, and the age at (first) marriage for women. Information on the former is only available for the period after the Black Death. This is because the percentage of females never married can only be established through family reconstitutions, which track cohorts over the entire life cycle. For the period before 1500, full reconstitutions are not available. The typical age at first marriage is easier to establish. In the European parts of the Roman Empire, it was 12-15 for pagan girls, and somewhat higher for Christian girls. Age at marriage in medieval times appears to be have been somewhat higher than in Roman times, but not by a large margin. For a group of Lincolnshire villages, Hallam (1985) estimated ages at first marriage for women of around 20.

Because the percentage never marrying is difficult to establish, we need to look at the proportion of women unmarried instead. Because the analysis necessarily refers to a particular point in time, it is possible that some of these women will eventually find husbands and have children – it is a strict upper bound on the percentage never marrying. In St Germain-des-Prés in 801-20, for example, some 16% of adults were unmarried.[12] In the 9th century, in Villeneuve-Saint-Georges, up to 12% of adults had never married (Hallam, 1985). We do not know how representative these figures are. There were regional exceptions. For 14th century Sussex, for example, there is little evidence of the European Marriage Pattern being in place (Mate, 1998). What is clear is that both a marriage age above the biological age of fertility, and a pattern of some women never marrying, probably had its origins in some areas at least in the period before the 14th century (Laslett and Wall, 1972).

The European marriage pattern in its full form emerged after the Black Death. According to Hajnal (1965, 1982), one of its key components is the postponement of marriage until age 25 and beyond. England in the early modern period registered an average age at first marriage for women of 26 years, and 17.5% never married. Scandinavia saw even higher ages at first marriage, but total fertility rates where greater than in England.[13] Table 1 gives an overview of the range of historical experience in the 17th century:

[Insert Table 1 here]

Within marriage, fertility was largely unconstrained. Table 2 shows marital fertility by age group, for Hutterites (a modern-day Canadian sect practicing no birth control), Western Europe before 1800, and China. Chinese fertility within marriage was low largely as a result of infanticide, as we discuss below. In 18th century Germany, some 20% of women married aged 30 and over (Knodel, 1988).

[Insert Table 2 here]

Northwestern Europe in particular evolved a 'low pressure demographic regime' (Wrigley, Davies, Oeppen, and Schofield, 1997). Negative economic shocks were largely absorbed through Malthus's preventive

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[12]Since men outnumbered women, the proportion of unmarried women was even lower.

[13]The difference is driven by a higher percentage of women never marrying in England.

check, rather than the positive check - births were curtailed through changes in nuptiality, instead of death rates surging. As economic conditions worsened, the system became more restrictive with respect to marriage. As life expectancy fell and conditions became less favorable, partly under the influence of declining land-labor ratios in England after 1600, the age at marriage increased, and gross reproduction rates fell (Wrigley and Schofield, 1981; Wrigley et al., 1997).

There are many reasons to believe that fertility restriction through late marriage was voluntary. Children were relatively independent from their parents by their teenage years, and became fully legally independent at age 21 – long before the average age of marriage. The law did not ban early marriages. In England, the legal age for marriage was 12 for women, 14 for men. Early marriages occurred, with the first age at marriage for women ranging from 16 to 45 (Clark, 2007). While the authorities attempted to raise age at marriage – by having extended apprenticeships, for example – there were plenty of ways to ignore or circumvent restrictions, especially in the larger towns (Ingram, 1985; Clark, 2007). Nor is there evidence that the "passion between the sexes" (as Malthus called it) was any less acute in early modern Europe than elsewhere. One out of seven marriages in 17th century England was followed by the bride giving birth within 8 months; the proportion could reach as much as 40% (Wrigley and Schofield, 1981).

2.2   Changes in Production and Consumption after the Black Death

Prior to the Black Death, European agriculture exhibited a trend towards declining labor productivity. Campbell (2000) argued that before the plague and the hunger crises of the early 14th century, output per head in English agriculture was falling. The more recent results by Apostolides et al. (2008) show declining agricultural production per worker and acre before 1350. Diets shifted from pastoral to arable products. These trends reversed after the Black Death. Immediately after the initial shock in 1348-9, prices of foodstuff collapsed by 45 percent, while cash wages increased by 25% (Campbell, 2000). These gains did not persist to the same extent for long, but the Black Death became a turning point for real wages regardless. By 1450, real wages in England were 50% higher than they had been on the eve of the plague, and more than twice as high as they had been before the Great Famine of the 1310s and 1320s.

Per capita consumption of food overall increased. As consumers grew richer, their consumption patterns shifted from 'corn to horn' (Campbell, 2000). There is ample evidence that "luxury foods" such meat, fish, and dairy products accounted for a far greater proportion of food expenditure after 1350 than before. Where grains had been consumed directly, as porridge or bread, ale-drinking expanded. Meat and milk consumption increased markedly. Based on changes in the number of non-working animals on farms, it approximately doubled. Since workers on large estates received some of their payments in kind, we also have more direct evidence on consumption patterns. Dyer (1988) analyzes the case of English farm workers, and shows that, for example, the percentage of calories coming from meat and fish rose from 7% in 1256 to 26% in 1424. By value, average spending increased from 20.5% pre-plague to 38.5% post-plague.

Landowners responded to the changes following the Great Plague in a number of ways. Apostolides et al. (2008) summarize changes after 1350 as follows:

"Between the mid-thirteenth century and the mid-fourteenth century, factor costs and property rights encouraged lords to manage their demesnes directly and concentrate on arable production. Following the Black Death, however, lords found it ... increasingly expensive to hire wage labour, following a substantial increase in wage rates. Those lords who continued to farm directly switched away from labour intensive arable production to mixed husbandry and pastoral production, leaving arable production to peasants who could rely mainly on family labour ...".

After 1350, pasture replaced arable land at a high rate. Meat and wool production thus came to be concentrated on the larger estates. Sheep-farming husbandry expanded everywhere, but the phenomenon was more pronounced in Southern England, especially the downlands. Campbell estimates that grain acreage declined by approximately 15 percent after 1349, while the number of livestock expanded by 40 percent to meet buoyant demand. Much of the increase was concentrated amongst livestock reared for meat and milk, which grew by 90 percent. Sheep-farming expanded, as did the ranching of cattle. The estimates of Apostolides et al. (2008) suggest that pastoral output (in constant prices) increased by 22% between 1348 and 1555, while arable output only grew by 7%. Since population was still below its medieval peak, per capita consumption grew even faster – by more than 40% by 1550 for pastoral products, while arable output was up by 23% (cf. Table 4). Milk production per head was up by 150%, beef by 130%, and pork by 280%.

[Insert Table 3 here]

In addition, agricultural production became much more capital-intensive. Given how costly labor was after the Black Death, landlords now had incentives to invest more in better ploughs and farm implements. The number of animals used as beasts of burden also grew. As Campbell (2000) points out, the use of horses and oxen for transport, as well as in ploughing, expanded.

Finally, the average farm size increased after the 14th century. While much attention has focused on parliamentary enclosures of the 18th century, there are good reasons to believe that the big rise in farm output between the plague and the onset of the industrial revolution was linked to an earlier process of enclosure - what Allen (1992) called the 'Yeoman's enclosure.' Some 80% of English farms had been smaller than twenty acres before the plague. By 1600, a majority - over 60% - of farms were larger than 100 acres. Increasing farm sizes allowed farmers to use more beasts of burden. Changes in capital intensity facilitated the saving of expensive (male) labor. The pattern emerging after the Black Death reversed the earlier trend towards declining labor productivity. Labor productivity began to grow, initially as a result of higher land-labor ratios. By the end of the early modern period, English agriculture had become capital intensive. It used massive investments in drainage, marling, and liming. In addition, English farmers used draft animals in great numbers. By the eighteenth century, the number of horses per worker was 80% higher than in France, and 40% higher per unit of land (Wrigley, 1988).

Higher incomes after the plague were not only spent on more meat and dairy products. They were also used to accumulate a growing number of consumer durables, as reflected in probate inventories. Dyer (1988) shows how the range of cooking utensils, furniture, ceramics, clothes, and decorations expanded quickly in

the late medieval period. While some of these were mainly made by skilled (male) craftsmen, others (in particular, textiles) were frequently produced by women.

2.3   Farm Service and Fertility Restriction

As in most agricultural socieites, children in their teens and twenties worked in Northwestern Europe – but they did so in an unusual way. An Italian visitor to England in the 16 century marvelled at the fact that, independent of parental income, parents would send their children away at an early age "for another 7 or 9 years... and few are born who are exempt from this fate" (McIsaac Cooper, 2005). Apprenticeships and service in agriculture were a standard part of an English adolescent's life. We briefly summarize how service in husbandry became a key institution that raised marriage ages in early modern England.

After 1349, all types of labor, including female labor, became more expensive. This effect was reinforced by changing patterns of agricultural production, and in particular, the increase in livestock production. As horn production increased, so did the labor demands of pastoral farming. Landlords increasingly hired 'productive servants' to help on the larger farms (Kussmaul, 1981). Pasturalism has fairly evenly-spread labor requirements throughout the year. This makes it attractive to employ servants year-round, instead of hiring agricultural laborers on daily wages. The latter, used mainly in the arable areas, are more suited to a production cycle characterized by a brief period of peak labor demand during the harvest season.

Pastoralism and the processing of its products is also singularly suited to the employment of women (Smith, 1981). Work as shepherdesses, as milkmaids or in spinning wool required less physical strength than plow agriculture. As the introduction discussed, working as a servant became an important part of many Englishwomen's life in the early modern period, with more than half of each cohort spending some time living in the house of the landlord in exchange for food, lodging, and pay.

For women and men, life as a servant in husbandry involved a commitment to remain unmarried. The *Museum Rusticum*, an 18th century periodical on rural affairs, called service "a covenanted state of celibacy." Marriage typically implied an immediate end to service. Kussmaul (1981) calculates that 65% of servants married immediately before or after the end of their contract (i.e., within a year of termination).[14] Upon marriage, servants would become economically independent, working as laborers or tending their own farm. The reason for these strict rules is that servants were entitled to room and board in exchange for labor services. Marriage and childbearing reduces female labor supply, and makes it more variable. As such, it would have been incompatible with the labor demands of pastoral agriculture. Thus, as Macfarlane (1970) observed, "the system of farming out the children, which permitted them a moderate freedom without forcing them to resort to marriage, allowed them to marry late."

Servants typically saved between half and two-thirds of their wages, with the intention of purchasing a small farm, moving to the city, or purchasing tools for rural manufacturing. The most common step upon marriage was to buy a farm. Enclosure during the early modern period increased average farm sizes (as discussed above). Where small farms disappeared, and working for day wages was the only option, farm

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[14]She also notes that in a number of cases, female servants were permitted to stay in the house of their master for the remaining duration of their contracts.

service declined in popularity. Thus, England's early modern fertility regime began to weaken once land holdings became too concentrated.

2.4   The Decline of EMP

English fertility increased rapidly during the second half of the eighteenth century. The causes of this marked change are not well-known, but a number of hypotheses have been advanced (Wrigley, 1983). England had had a particularly strong, "low-pressure" form of the European Marriage pattern, with late marriages and low rates of illegitimacy. Mean ages at first marriage had begun to trend down for both men and women after the 1730. By the the 1830s, they had fallen from 26 for women (and 27 for men) in 1700 to 23 (and 25, respectively). Illegitimacy, which had accounted for a mere 1% in the 1650s, rose to more than 6% after 1800. Population growth accelerated from zero to 1.75% per annum (Wrigley et al. 1997).[15]

As the eighteenth century wore on, a number of factors reduced female employment opportunities in husbandry. Snell (1981) argues that as grain prices rose in the 18th century relative to the price of meat and dairy products, pastural production declined. In addition, land productivity in English agriculture began to rise after 1700 (Apostolides et al., 2008). Since meat production was more land-using than grain production, this made pastoralism overall less profitable. However, lower wages for female labor alone cannot be a sufficient explanation – based on the classic pattern in early modern England, this would simply raise the marriage age.

We argue that the institution of farm service for young women itself was gradually vanishing, as a result of economic change. This is what the seasonality of marriages shows. There were typically two pronounced peaks in the marriage cycle - in May/June and September/October. These reflected the end of the hiring cycle for servants - spring in husbandry, after the lambing season, and fall in arable farming, after the harvest. These peaks gradually became smaller after the 17th century. Importantly, as Kussmaul (1988) shows, the overall marriage age and the proportion of spring marriages fell in tandem. These marriages, held after the lambing and shearing season brought the typical work-year in pastoral agricultural to an end, became markedly less important after 1700 (Figure 1). Thus, late marriage and horn production declined in parallel.

[Insert Figure 1 here]

Economic changes behind this simultaneous decline probably included the rise in farm sizes already mentioned, which put the purchase of a small farm beyond the means of the most frugal servants. Second, as agricultural employment as a percentage of the total fell, the annual hiring cycle for servants in agriculture left less and less of a trace in the seasonality of marriages. Cottage shop manufacturing offered a chance to earn a living, while already having children.[16] For any given decline in the land-labor ratio, female wages

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[15]Wrigley (1983) examined the contribution of fertility to the acceleration in population growth after 1750. Some of the underlying data has been revised by Wrigley et al. (1997), but the relative contributions of fertility increase and mortality decline have not been recalculated.

[16]The effect on marriage age is not always clear-cut. Some studies find a decline in the age at first marriage for women in

fell by less; thus women could marry earlier, and still earn the same. The fall of England's low fertility regime may therefore have been brought on by the same factors that determined its rise during the early modern period – changes in the opportunity cost of female labor in the late teens and early twenties, as determined by employment conditions for servants in husbandry.

2.5 Chinese Demography

That Chinese fertility was 'unconstrained,' compared to Europe, has been a staple of the demographic literature since the days of Malthus. Malthus himself, in his discussion of the positive and the preventive checks, emphasized that only Europe appeared to have evolved an elaborate system where the latter operated effectively. It appears that Malthus was (partly) wrong. The age at first marriage was low in China, and marriage was near-universal for women, as Malthus had emphasized. However, two other factors limited fertility - infanticide and low fertility within marriage (Lee and Feng, 1999). Especially female children were killed often, either directly, or through neglect. This reduced fertility rates. In addition, fertility within marriage may well have been 25-50% lower in China than in Europe (Table 2). Chinese fertility restraint appears partly to have been driven by an early end to childbearing (Feng, Lee, and Campbell, 1995), greater birth spacing due to extended breastfeeding, as well as a longer delay between marriage and the first birth (Wolf, 2001).

Some of the revisionist evidence collected by Feng et al. (1995) has been called into question. It is based on potentially unrepresentative samples, and births may be under-counted (Wolf, 2001). What is clear is that earlier authors, writing in the tradition of Malthus and Adam Smith, exaggerated the extent to which Chinese fertility was 'unconstrained.' Early and universal marriage did not boost fertility as much as might be expected since within-marriage fertility was lower than in Europe. While the reasons behind the low rates of child bearing are not well-known, poor nutrition leading to infertility may have been a factor. Data from the 19th century suggests that Chinese birth rates were around 35/1000, only slightly higher than early modern European ones (Clark, 2007). This could be interpreted as a sign that differences between European and Chinese fertility behavior have been overstated. Yet Chinese incomes were much lower. Thus – since European fertility increased in wages – fertility rates were higher in China than in Europe *for any given wage*. Even if the realized fertility rates were not too different, the European fertility rate conditional on income was much lower.

Overall, Chinese population growth rates were not as high as they could have been in the absence of infanticide and limited marital fertility. Chinese population size increased by a factor of over 5 between 1400 and 1820, while Europe only grew by a factor of 3.2 - annual population growth rates were 0.4% and 0.28%, respectively. In other words, Chinese population growth was approximately 1/3 faster than in Europe, largely as a result of early and universal marriage.

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proto-industrializing areas; others show that higher nuptiality preceded the spread of cottage-shop manufacturing (cf. Hudson, 1996).

3 Model

This section presents a simple model that captures the basic mechanisms determining pre-industrial labor supply and marriage decisions. The economy is composed of N peasant households – each formed by one couple – who work, consume, and procreate. People live for two periods. In the first period of life, they are children and do not work or consume. In the second period of life, people are adults. Male and female adult peasants are endowed with one unit of time each. Men always work. Therefore, total male labor supply is given by $L_M = N$. Women allocate their time between work and marriage. When married, women do not work; they spend all their time raising children. For simplicity, we assume that wages are the only source of income for peasants. Couples make joint decisions to maximize household utility, facing a tradeoff between female work time and raising children. There is also one landlord who owns all land T, which is in fixed supply. The landlord does not work. Peasants rent a fixed amount of land, T_p on aggregate, from the landlord. In addition, the landlord owns land $T_k = T - T_p$ that is not rented out to peasant farmers; instead, farmers are paid to work on his land.[17]

There are two technologies to produce consumption goods. Both use land and peasant labor as inputs. Grain production uses physical labor intensively. Men have a large comparative advantage. Second, cow-herding and sheep-farming requires less arduous labor. Women and men are equally productive. In addition, pastoral agriculture needs a minimum land size to be productive – enough land to graze livestock. Historically, cattle ranches and sheep farms have been much larger than arable farms. Pastoral agriculture therefore exhibits increasing returns.

The economy is Malthusian – there is a unique long-run equilibrium income level. It depends on fertility and mortality schedules. The latter declines in consumption. Fertility, on the other hand, is endogenous and depends on the age at marriage. Before marriage, women do not have children. During marriage, there is no birth control and children arrive with the frequency π. Delaying marriage is therefore the only 'contraception technology.'

An epidemic like the plague causes land-labor ratios to rise dramatically. This leaves the remaining population with greater per-capita income. As long as birth and death schedules are unchanged, the economy returns to its earlier equilibrium – any escape from Malthusian stagnation is temporary. However, in our model, the plague prompts the landlord to shift production from "corn to horn." Cattle and sheep farming use the abundant factor of production – land – and can be operated with cheap labor – that of women. Thus, the demand for female labor rises, and so do female wages. Women marry later, and work for a greater fraction of their lives. The "European Marriage Pattern" is born. We argue that this mechanism captures an important element of the European experience in the centuries between the Black Death and the Industrial Revolution. The new equilibrium has lower birth rates, combined with higher per capita incomes. This mechanism can explain the slow convergence back to pre-plague population levels after 1349, and the persistence of higher output per capita.

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[17]To avoid confusions with labor l, we use the subscript k for the landlord – recalling that kings owned large land areas may serve as a mnemonic.

3.1 Household Formation and Fertility

In each period, a male and a female peasant meet and form a new couple. Independent of whether or not they live in the same location, they make decisions jointly, maximizing household utility. Once women leave the labor force, man and wife move in together. Since each man supplies one unit of labor inelastically throughout his lifetime, men's contribution to household income is equal to the male wage rate w_M. Female labor supply $l_F \in [0,1]$ is determined by the trade-off between female wage income w_F and child rearing. In our simplified framework, women are only productive in horn production. This technology is operated only by the landlord due to minimum size requirements. When working for the landlord, women live separated from their fiancé. The fraction l_F of lifetime can therefore be interpreted as the celibate period for both men and women. The probability of childbearing is zero. The fraction $1 - l_F$ is the share of lifetime that couples are married. There is no contraception. Married couples produce π births per unit of time. Therefore, the number of offspring per couple is given by

$$b = \pi(1 - l_F) \tag{1}$$

Women do not work during marriage; they exclusively care for their children. The survival rate of children depends on average consumption of peasants. Among adults, death rates are zero until the period is over. The number of children per family that die is given by

$$d = d_0 \left(\bar{C}_p / \underline{c} \right)^{\varphi_d} , \tag{2}$$

where $\varphi_d < 0$ is the elasticity of child mortality with respect to average consumption of peasant households ($\bar{C}_p$), and d_0 is the death rate at subsistence consumption $\underline{c}$. Consequently, child mortality falls as p.c. income rises. At the end of each period, parents die and surviving offspring form the next adult generation.

There is no investment or bequests to children – all income is spent for consumption during the adult period of life. Both men and women draw utility from the number of children and from consuming two goods: Grain ($c_{p,g}$) and horn products (meat, wool, textiles – denoted by $c_{p,h}$). We use grain as the numeraire; the price of horn goods is denoted by p_h. Both goods enter household utility via the composite consumption index $C_p = C(c_{p,h}, c_{p,g})$, which takes the form of a CES aggregator. A detailed specification is not needed at this point; we introduce the functional form when we close the model below. The corresponding price index is $\Omega(p_h)$, and the peasant household's budget constraint takes the form $\Omega C_p \leq w_M + w_F l_F$. When consumption exceeds subsistence, $C_p > \underline{c}$, household utility is given by

$$u(C_p, b) = (1 - \mu) \ln(C_p - \underline{c}) + \mu \ln(b - \underline{b}) \tag{3}$$

where $\mu \in (0,1)$. This is similar to Galor and Weil (1996) and is a special case of Jones' (2001) model.[18]

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[18] In the more general setup, rising income in a rich economy ($C_p >> \underline{c}$) has two effects: An income effect (richer peasants want both more children and consumption) and a substitution effect (a shift away from children towards work, which becomes more rewarding with increasing productivity). In our setup with log-preferences, income and substitution effect cancel each other so that

For now, we assume that peasant household income is large enough for consumption to exceed subsistence, $C_p > \underline{c}$. We discuss the case $C_p \leq \underline{c}$ below.

The landlord does not work and does not draw utility from children. However, he has the same consumption preferences as peasants, $C_k = C(c_{k,h}, c_{k,g})$. His only source of income are land rents, rT, and his budget constraint is given by $\Omega C_k \leq rT$.[19]

Given w_M and w_F, peasant households maximize (3) subject to the time constraint $0 \leq l_F \leq 1$, the birth rate given by (1), and their budget constraint. In the absence of bequests and investments, the latter holds with equality, i.e., $\Omega(p_h)C_p = w_M + w_F l_F$. The household optimization problem is then given by

$$\max_{l_F} = (1 - \mu) \ln \left(\frac{w_M + w_F l_F}{\Omega(p_h)} - \underline{c} \right) + \mu \ln \left(\pi(1 - l_F) - \underline{b} \right) \tag{4}$$

The landlord draws utility from consumption only, based on the same preferences as peasant households. However, he does not care about children and therefore does not influence fertility directly.

The optimization problem is static, which simplifies our analysis. This is similar in spirit to Jones (2001) and can be derived from a more general dynamic optimization problem under two assumptions that we have made. First, utility depends on the flow of births rather than on the stock of children. That is, parents care about their own children, but not about their children's offspring. Second, we assume in (2) that child mortality depends on average per capita consumption. Since households take average consumption as given, child mortality does not interfere with optimal labor supply decisions.[20] With these assumptions, the more general dynamic optimization problem (e.g., Barro and Becker, 1989) reduces to a sequence of static problems as given in (4).

3.2 Technology

There are two consumption goods in our model: grain (g), and horn products (h), such as meat, milk, or wool. The grain technology uses labor and land as inputs. Men have a relative advantage compared to women because arable farming requires intense physical labor, such as ploughing, threshing, and reaping. For simplicity, we assume that women are completely unproductive in grain production. Grain production follows:

$$Y_g = A_g L_M^\alpha T_g^{1-\alpha} , \tag{5}$$

where T_g and L_M, respectively, denote land and male labor employed in producing grain.

The horn technology uses labor, land, and livestock (calves or lambs) as inputs. Cattle production is less physical-labor intensive than producing grain. Consequently, it is a more suitable technology for female labor. Women are therefore *relatively* more productive in horn production. In they stylized model, we

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birth rates are constant when $C_p >> \underline{c}$. This choice allows us to focus on the subsistence effect that operates when C_p is close to $\underline{c}$.

[19]While land-owners were not consuming goods in the same proportions as peasants, the staff they employed in large numbers were. We abstract from any systematic differences for ease of exposition.

[20]A historical justification is that the main cause of child mortality were diseases like diarrhea and typhus, whose spread depends on hygienic conditions (and therefore income) in the community.

assume that men are unproductive in horn production:[21]

$$Y_h = A_h L_F^\alpha T_h^{1-\alpha} - \varrho L_F \ , \tag{6}$$

where L_F is female labor and T_h is land used in horn production. The parameter $\varrho > 0$ is related to a fixed cost in output *per worker*. When producing horn, young livestock is needed as an initial input, which is costly. The larger the production scale, the more livestock input is needed. The overall input cost in horn production is thus scale-dependent.[22] For horn to be produced, the land-labor ratio must be high – a condition provided by the Great Plague of the 14th century.

In addition, we assume that the horn technology is only available to owners of large land areas, i.e., to the landlord in our model. Historically, this is motivated by the size differences of farms in areas of pastoral vs. arable cultivation (Campbell, 2000). Analytically, a minimum land requirement for horn production would provide an alternative specification with similar implications for who engages in production. To save on notation and concentrate on the main mechanism, we do not model this dimension explicitly. Instead we assume that only the landlord produces horn. This assumption is important because, together with the fact that female labor is productive only in the horn sector, it ensures that women have to leave the household to work.

3.3   Location of Production

The landlord owns an area T of land. He leases a fixed part T_p to peasants and manages the remainder, employing hired labor. Each farming household therefore rents land T_p/N. Peasants do not have access to the large scale horn technology and therefore use all their rented land to produce grain. Let $L_{M,p}$ denote the total amount of male labor employed in peasant production. The total output of grain, produced by peasants, then follows from (5):

$$Y_{g,p} = A_g L_{M,p}^\alpha T_p^{1-\alpha} \tag{7}$$

The landlord hires labor at its marginal product to produce grain and – under the conditions specified below – horn on the remainder of the land, $T_k = T - T_p$. The landlord's grain production is therefore given by

$$Y_{g,k} = A_g L_{M,k}^\alpha T_{g,k}^{1-\alpha} \ , \tag{8}$$

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[21]What accounts for our main result is that women have a *comparative* advantage in horn production. To keep matters as simple as possible, we assume an absolute productivity advantage. However, for the model parameters we use below, wages in horn production are always below the ones in grain farming, so that men would always opt for employment in grain production. A more general setup would use a CES technology, where men and women are imperfect substitutes and the labor composite is given by $\left(\tau_i L_{M,i}^\sigma + (1-\tau_i) L_{F,i}^\sigma\right)^{\frac{1}{\sigma}}$ for $i = g, h$ and with $\sigma \in (0, 1)$. In the general case, we have $\tau_g > \tau_h$, i.e., men have a comparative advantage in the physical-labor intensive grain production. Our stylized setup uses $\tau_g = 1$ and $\tau_h = 0$.

[22]More specifically, suppose that each unit of labor can tend $\hat{\varrho}$ pieces of livestock. More tending does not increase productivity, whereas less tending lowers output proportionately because cattle or sheep can escape, predators take their toll, etc. The production function (6) is then given by $Y_h = A_h \left(\min\{S/\hat{\varrho}, \ L_F\}\right)^\alpha T_h^{1-\alpha}$, where S denotes the stock of cattle and sheep. Optimal production requires $S = \hat{\varrho} L_F$, i.e., one unit of labor tending $\hat{\varrho}$ heads of cattle. Young cattle are costly; suppose that their price (in terms of grown-up cattle) is p_S. Then the livestock input cost of producing Y_h units of horn is $p_S S = p_S \hat{\varrho} L_F$. Defining $\varrho \equiv p_S \hat{\varrho}$ yields the production function (6).

where $T_{g,k}$ is the land that the landlord allocates to grain production, and $L_{M,k}$ denotes the corresponding male labor input. In the absence of horn production, $T_{g,k} = T_k$. Otherwise, the landlord dedicates T_h to graze cattle and sheep, such that $T_{g,k} + T_h = T_k$.[23] This production involves only female labor. The landlord's horn output is thus given by (6).

This description finishes the setup of our basic model. Next, we show how male labor is allocated between production on the peasants' and the landlord's soil. In addition, we examine the female labor supply decision.

3.4 Factor Payments and Allocation of Labor

Male peasants optimally allocate their labor supply between working on rented soil – paying rents to the landlord while keeping the remaining output – and working for the landlord for a wage rate $w_{M,k}$. When working on rented land, the marginal product of peasant labor is given by

$$w_{M,p} = \alpha A_g \left(\frac{T_p}{L_{M,p}} \right)^{1-\alpha} = \alpha A_g \left(\frac{t_p}{l_{M,p}} \right)^{1-\alpha} , \tag{9}$$

where $t_p = T_p/N$ is the land per household in peasant grain production on rented land, and $l_{M,p} = L_{M,p}/N$ is the share of male labor allocated to rental-soil production. Peasants pay the rental rate

$$r_p = (1-\alpha)A_g \left(\frac{l_{M,p}}{t_p} \right)^{\alpha} . \tag{10}$$

The landlord pays workers their marginal product. In the case of grain production on the landlord's own fields, this implies

$$w_{M,k} = \alpha A_g \left(\frac{t_{g,k}}{l_{M,k}} \right)^{1-\alpha} , \tag{11}$$

where $l_{M,k} = L_{M,k}/N$ denotes the share of male labor spent working for the landlord. Land per household in the landlord's grain production is given by $t_{g,k} = T_{g,k}/N$. Peasants maximize wage income, from both working on rented soil and from working for the landlord. Thus, marginal returns to both types of employment must equalize: $w_{M,p} = w_{M,k}$. Using this together with (9) and (11) we obtain:

$$\frac{t_{g,k}}{l_{M,k}} = \frac{t_p}{l_{M,p}} , \tag{12}$$

that is, the land-labor ratio in grain production is the same on peasant-rented and landlord-operated soil.

When the landlord also produces horn, sold at price p_h, the corresponding female wage rate follows from (6):

$$w_F = p_h \left(\alpha A_h \left(\frac{t_h}{l_F} \right)^{1-\alpha} - \varrho \right) , \tag{13}$$

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[23]Since only the landlord's land is large enough for horn production, an additional subscript k is not necessary – whenever we talk about Y_h it is produced by the landlord.

where $l_F = L_F/N$ is the share of their lifetime that women spend working. Optimal allocation of the soil operated by the landlord requires that the land return to horn and grain production equalize. Using (6) and (8), this implies

$$r_k = (1 - \alpha)A_g \left(\frac{l_{M,k}}{t_{g,k}}\right)^\alpha = p_h(1 - \alpha)A_h \left(\frac{l_F}{t_h}\right)^\alpha . \tag{14}$$

Therefore, in equilibrium, the land per worker in the landlord's horn production is proportional to its counterpart in grain production:

$$\frac{t_h}{l_F} = \left(\frac{p_h A_h}{A_g}\right)^{\frac{1}{\alpha}} \frac{t_{g,k}}{l_{M,k}} , \tag{15}$$

where the factor of proportionality is given by the price-augmented TFP ratios – relatively more land is dedicated to the more productive technology. Given these equilibrium conditions, we can characterize the economy with and without horn production.

Grain production only

In the absence of horn production women do not work, because the technology that uses their labor input does not operate. Marriage occurs early; birth rates are constant and high, $b = \pi$. Male labor input on land leased from the lord of the manor follows (12) and is given by $l_{M,p} = t_p/t = T/T_p$, where $t = T/N$ is total land per household.[24] As long as horn production is not profitable, the share of male labor performed on rented land is constant. In the grain-only economy, labor shares stagnate even if wage levels change.

Production of grain and horn

Things look different when the horn technology is employed. In this case, female labor supply is positive. Male labor allocation also changes because the landlord changes land allocation in favor of 'horn.' We combine (12) with (15) and substitute for t_h/l_F in (13). This yields

$$w_F = p_h \left(\alpha A_h \left(\frac{p_h A_h}{A_g}\right)^{\frac{1-\alpha}{\alpha}} \left(\frac{t_p}{l_{M,p}}\right)^{1-\alpha} - \varrho\right) . \tag{16}$$

Female wages are therefore driven by three important components in our model. First, by the land-labor ratio in peasant grain production, $t_p/l_{M,p} = T_p/L_{M,p}$: If land is relatively scarce because of population pressure, w_F is negative. The horn technology is not profitable because it depends on abundant grazing land. Due to the large population losses during the plague, the land-labor ratio rises dramatically. As a consequence, w_F becomes positive, and horn production becomes profitable. Second, female wages depend on the relative price of horn products. If p_h is low, w_F is negative, and the technology is not employed. Finally, if grain technology is highly productive relative to horn technology, little land is dedicated to the

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[24]To obtain this result, recall that T_p is fixed. If the landlord produces only grain, $T_{g,k} = T_k = T - T_p$ is also fixed, implying $t_k = t - t_p$. In addition, $l_{M,k} = 1 - l_{M,p}$, i.e., men spend a share $l_{M,p}$ of their lifetime working on the land they rent, and spend the remainder as laborers on the landlord's soil.

latter, rendering negative female wages. Thus, the horn technology is employed when (i) the land-labor ratio is high, (ii) there is sufficient demand for horn products, and (iii) grain technology is not too productive relative to horn.

3.5 Fertility and Female Labor Supply

The missing piece to close the model is female labor supply. We derive it as a function of male and female wage rates. Households desire at least $\underline{b}$ children; women cannot work more than $\bar{l}_F = \underline{b}/\pi$. The household optimization problem (4) then yields:

$$b - \underline{b} = \pi(\bar{l}_F - l_F) = \pi \, \frac{\mu}{1-\mu} \, \frac{w_M + w_F l_F - \Omega(p_h)\underline{c}}{w_F} \tag{17}$$

In this setup, a subsistence effect governs fertility decisions. To describe it, we analyze a relatively poor economy, where peasant income $w_M + w_F l_F$ is close to, but larger than, the expenditure needed for subsistence consumption, $\Omega(p_h)\underline{c}$. In addition, assume for the moment that $\varrho \to 0$ in (16). In the absence of major changes in p_h, w_F is then linearly proportional to w_M, which follows from (9) and (16). Now suppose that productivity *falls*, pulling income yet closer to the subsistence level. Then the marginal utility of consumption rises dramatically and female peasants work more, giving birth to fewer children.[25] Therefore, the subsistence effect implies that income and birth rates move in the same direction. The same argument holds when $\varrho > 0$, as long as it is sufficiently small relative to the productivity term in (16), such that the horn technology is employed. We argue that this reflects the European experience after the plague, where horn production was feasible due to high land-labor ratios, and birth rates moved in parallel with income.

3.6 Static Equilibrium with Linear Consumption Utility

In this section we close the static model. We take overall population as given and solve for wages, female labor supply, and birth rates. We first have to specify the composite consumption index $C(c_g, c_h)$. In order to focus on the main mechanism of our model, we simplify the analysis by assuming that grain and horn products are perfect substitutes.

$$C = c_g + c_h \tag{18}$$

Conveniently, this implies that the price of grain equals the price of horn, provided that the latter is produced. Consequently, $p_h = 1$ and $\Omega(p_h) = 1$ – relative price effects do not influence our results. Of course, perfect substitutability between two types of food is a strong assumption. However, evidence suggests a high elasticity. We already discussed the large rise in the share of calories coming from meat and fish in England after the Black Death. In other areas of world, where populations of European origin were faced with cheap and abundant meat (such as in Argentina), consumption also grew massively.[26]

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[25]This continues until the number of children falls to $\underline{b}$, where the constraint $l_F \le \bar{l}_F$ is binding.

[26]In the 1980s, Argentine beef consumption was 70-80 kg per capita, twice as high as in the US (Jaffee and Gordon, 1993). In the 19th century, it may have been as high as 120 kg (Salvatore, 2004). Our mechanism is robust to using CES preferences; the

We distinguish three cases for the model economy: (i) a land-abundant one, where both technologies operate and peasant consumption C_p is above subsistence; (ii) a more land-scarce economy with both technologies but below-subsistence consumption, and (iii) an economy with very small land-labor ratios where the horn technology is not profitable. We choose ϱ such that (ii) precedes (iii) as land becomes more scarce, i.e., such that the horn technology is still profitable when consumption is at the subsistence level.

Grain and horn production

We start by describing the equilibrium where peasant consumption exceeds subsistence, i.e., $w_M + w_F l_F > \underline{c}$, and both technologies operate. Market clearing in this case requires that total income (peasant households' wages and the landlord's rents) is spent for grain and horn consumption:

$$N(w_M + w_F l_F) + rT = Y_g + Y_h \tag{19}$$

where Y_g (Y_h) denotes aggregate production of grain (horn). Male wages on rented and landlord-operated soil equalize. The same is true for the rental rate in grain and horn production. Substituting (5), (6), and (10) into (19), we obtain:

$$w_M + w_F l_F + (1-\alpha)A_g\left(\frac{l_{M,p}}{t_p}\right)^\alpha t = A_g\left(\frac{t_p}{l_{M,p}}\right)^{1-\alpha} + l_F\left[A_h\left(\frac{A_h}{A_g}\right)^{\frac{1-\alpha}{\alpha}}\left(\frac{t_p}{l_{M,p}}\right)^{1-\alpha} - \varrho\right] \tag{20}$$

We now have a system of 4 equations: (9), (16), (17), and (20) with 4 unknowns: w_M, w_F, $l_{M,p}$, and l_F, which determine the equilibrium when peasant consumption is above subsistence. This completes case (i); next, we turn to case (ii).

With falling land-labor ratios, peasant consumption approaches the subsistence level. The marginal utility of consumption surges, boosting female labor supply. Eventually, the female labor supply constraint becomes binding: $l_F = \bar{l}_F$, and this constraint replaces (17) in the system of equations.[27] As long as both technologies operate, the remaining equations are unchanged, even if consumption is below subsistence. This completes the two cases where both grain and horn goods are produced. Next, we turn to the grain-only economy.

Only grain production

For small land-labor ratios, female wages in (16) become negative. The landlord cannot generate a profit from animal husbandry. This pushes women out of the labor market. Consequently, $l_F = 0$ and horn goods

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corresponding simulation results and equations are available upon request.

[27] We do not explicitly model utility for the below-subsistence case. However, it is clear that any specification with sufficiently large marginal utility of consumption will induce ample female labor supply such that $l_F \leq \bar{l}_F$ is binding.

are not produced. Market clearing thus applies to grain only, such that (20) simplifies to

$$w_M + (1 - \alpha)A_g \left(\frac{l_{M,p}}{t_p}\right)^{\alpha} t = A_g \left(\frac{t_p}{l_{M,p}}\right)^{1-\alpha} . \tag{21}$$

This equation together with (9) determines the relevant variables, w_M and $l_{M,p}$. We have now solved the static model for all three cases and turn to simulation results.

Simulation results

We present all model results as a function of land per peasant household, $t = T/N$. Figure 2 shows the labor and land allocation. For very small land-labor-ratios, the horn technology does not operate, because the fixed costs ϱ exceed the productivity term in (16). Consequently, women do not work, and no land is allocated to horn production. In addition, birth rates are high because couples marry early, given that women do not work in husbandry (right panel of Figure 3).

[Insert Figure 2 here]

As land per household increases, the horn technology eventually becomes feasible. Because consumption is still below subsistence, incentives to work are huge. Female labor supply is at its upper bound $\bar{l}_F = \underline{b}/\pi$, such that only $b = \underline{b}$ children are born per peasant household. The landlord now uses part of his soil for horn production and dedicates less to grain. This reallocation of land leads to a redistribution of male labor shares. Male farmers spend more working time on the land that they rent (right panel of Figure 2). In addition, with women working, overall labor supply increases, which leads to a redistribution of income from peasant households to the landlord (left panel of Figure 3). Finally, we consider the case where soil is abundant enough to allow for above-subsistence consumption. Female labor supply decreases with growing t, because the need for consumption (and thus work) becomes less severe. Facing a trade-off between consumption and family life, richer households opt for the latter. This subsistence effect is responsible for the upward sloping fertility schedule. Fertility rises with the land-labor-ratio, but does not reach the previous extreme level where horn production did not occur. This reflects the main features of EMP – a downward shift of birth rates with a simultaneous upward-sloping pattern.

[Insert Figure 3 here]

4   International Comparisons

Western Europe was not the only area to suffer from the Black Death or other devastating plagues. Yet it is the only one to have evolved a regime of fertility restriction based on a socio-economic institution that avoided births through delayed marriage. In this section, we examine how other regions fared – and why they did not evolve a similar way of reducing fertility.

4.1   Divergence within Europe

Fertility control in Northwestern Europe was particularly stringent. In Southern Europe, EMP reduced fertility by less. In Eastern Europe, EMP did not exist at all. Why did such contrasts prevail within Europe?

In Southern Europe, both age at first marriage and the percentage never marrying were lower than in the Northwest. There, population recovered relatively quickly from the impact of the Black Death. In Italy and Spain, it returned to the pre-1350 peak by the 16th century. In contrast, England probably did not reach pre-plague population levels until the 17th or even the 18th century.[28] Rapid recovery of Southern European populations also reversed post-plague wage gains. Changes in agriculture were also less pronounced. In particular, while the temporary spike in incomes after 1350 improved wages, it did not lead to the evolution of service as a standard phase in the transition from childhood to adulthood. If the shock of the plague was similar, why did it not cause a similar host of social and economic changes?

Agricultural conditions in Mediterranean countries did not favor the pastoral farming of the type common in Northwestern Europe. Land productivity was often even lower than in Northern Europe. In particular, low rainfall made it impossible to keep large herds of cattle and sheep in the same area year-round. Transhumance – the driving of livestock from one area to another – is an ancient custom in Mediterranean countries, with numerous routes recorded as far back as Roman times. The most famous is arguably the Spanish Mesta – a council of shepherds that controlled transhumance under a grant from the Spanish King, allowing them to drive their flocks across a vast stretch of territory extending from Extremadura and Andalusia to Castile.[29] Thus, where the grass was not green enough for year-round husbandry, female employment opportunities were reduced. Traversing sparsely populated areas on their own was not compatible with their social role in early modern Europe. Work in husbandry remained a male occupation. Without the rise of service in husbandry as a typical phase in young woman's life, marriage ages remained low.

In Eastern Europe, the plague did not strike with the same force as it did in Western Europe. Instead of arriving from Mongolia via the Russian steppes, the disease took a detour via the Black Sea and the Mediterranean to reach Europe. While the reasons for the disease not spreading via land-routes are not clear, the low population densities in Russia's Western steppes cannot have helped transmission. Population declines in Eastern Europe were therefore probably smaller than they were in the West. Without a major jump in land-labor ratios, cattle and sheep farming remained uncompetitive vis-a-vis grain production. In addition, productivity in grain production was unusually high. Especially in Western Russia and Ukraine, land is unusually fertile, even by Northern European standards (Nunn and Qian, 2009). Landlords continued to farm their estates using serf labor in arable production. During the early modern period, large grain surpluses were often exported.

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[28]There is considerable uncertainty about the size of the pre-plague population in England. Slow recovery was not a universal feature of the Northwestern European experience – the Netherlands experienced rapid population growth (Pamuk, 2007).

[29]Originally, shepherds took advantage of the agricultural no-man's-land between Christian and Muslim areas of control. Gradually, the use became institutionalized.

4.2 Comparison with China

Can our model account for the different experience in China? The Middle Kingdom also suffered from a devastating plague outbreak in the 14th century. While we do not have direct evidence, wages and output per head must have increased temporarily. Why did the same shock, in an area suffering from declining marginal returns to labor, not lead to the emergence of a 'low pressure' demographic regime?

European farms were substantially larger than Chinese ones. Table 3 compares farm sizes in the most advanced areas – England and the Yangtze Delta. Compared to pre-plague English farmers, Chinese peasants tilled land that was between one third and one quarter in size. After the Black Death, English farm sizes grew dramatically, increasing by a factor of five by 1600. By 1800, they had doubled yet again, to 150 acres despite growing population pressure. In China, continuous population growth, combined with the practice of partible inheritance, put downward pressure on farm sizes. In the two centuries after 1400, they fell by between 25% and 50%, before declining to about one acre by 1800. At the dawn of the nineteenth century, English farms were thus, on average, 150 times larger than Yangtze ones. According to the calculations by Allen (2007), land productivity in the Yangtze Delta was 9 times higher than in the English midlands, mainly because labor input per acre was higher by a factor of 10.

The second distinct difference between Chinese and European agriculture concerns the use of draft animals, and the prevalence of pastoral farming in general. While Chinese 16th century writers observed that 'the labor of ten men equals that of one ox,'[30] the use of draft animals declined in the Ming and Qing period. Animal use disappeared almost entirely, except for the most arduous tasks, by the mid-Qing period.[31] The reason is that labor was cheap, while the land needed to feed an ox was dear. Most farms were also too small for keeping an ox. Chinese farmers demonstrated great ingenuity in finding ever more ways to use human labor to raise yields per hectare. To the annual rice crop, winter wheat was added, as well as multiple rounds of fertilizer spreading that enhanced soil fertility (Goldstone, 2003).

Ever smaller farm sizes in China also meant that there was much less scope for female employment in agriculture. Only rice and grain cultivation requiring great physical strength remained, and the labor requirements could be satisfied by the existing male labor force on the small plots. As Li (1998) has argued, women were increasingly rendered superfluous for agricultural tasks, which were also less and less well-matched to their comparative advantages. They consequently sought employment outside agriculture, in home production of textiles through spinning and weaving. Overall, the 'market value' of female labor declined during the Ming and Qing periods, as a result of falling labor productivity combined with changes in the pattern of production arising from growing 'agricultural involution' (Berkeley, 1963). Even authors skeptical of the involution hypothesis conclude that female wages were only 25% of male wages in 1820s China, whereas English women's wages were equivalent to 50-63% of English male wages (Kussmaul, 1981; Allen, 2007).

To capture the Chinese experience in our model, we leave all parameters unchanged except one – grain

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[30]Cited after (Brenner and Isett, 2002).

[31]The view is controversial. Wider availability of bean cake may have helped the increased use of oxen after 1620 (Allen, 2007).

productivity in England is lower, i.e., $A_g^{\text{England}} < A_g^{\text{China}}$, while $A_h^{\text{England}} = A_h^{\text{China}}$. Consequently, land-labor ratios for any given wage are higher in England – more land is needed to sustain a given population. This is shown in the lower panel of Figure 4.[32] Horn production is at a *relative* disadvantage in China. It becomes profitable – relative to highly productive arable production – only at very high land-labor ratios, i.e., very high wages. Under plausible parameter values, the switch to horn production never occurs. Consequently, even after the plague hit China and raised p.c. income, horn technology remained uncompetitive.

[Insert Figure 4 here]

English grain production is not sufficiently efficient for the economy to be in the 'danger zone.' That is, horn production is feasible even at relatively low land-labor ratios. As the plague hits, consumption passes the threshold level and peasants start to have the means for buying meat and wool. To satisfy this demand, female labor supply jumps, and fertility declines. The economy converges to the new stable equilibrium E_H with lower birth rates and higher p.c. income. In China, on the other hand, the plague does not trigger the emergence of a demographic regime comparable to EMP because even high land-labor ratios cannot compensate for the productivity advantage of grain production. The only long-run equilibrium is E_L, with low p.c. income levels.

In a paradoxical way, China's high land productivity, as emphasized by the revisionist 'California School' (Pomeranz, 2000; Goldstone, 2003), undermined its prospects of adopting fertility limitation along English lines. Our minimalist model thus captures five important elements of the divergence between England and China: (i.) No emergence of female labor outside the household in China, (ii.) Limited livestock production, (iii.) Low land-labor ratios, (iv.) High(er) fertility through early (and near-universal) marriage, and (v.) Lower per capita incomes.

Calibration and Magnitude of EMP Impact

This final section examines EMP's contribution to sustaining higher p.c. income levels after the Black Death. We focus on England, where births were particularly responsive to economic conditions (Lee, 1981; Wrigley and Schofield, 1981). We follow two strategies, using first our simple model and then turning to historical estimates. For the former, the central parameters are $\pi = 3$ (women have three children when not working), $\underline{b} = 2$ (two children is the lower bound for birth rates), $\mu = 0.2$ (importance of offspring relative to consumption), $\alpha = 0.6$ (labor income share in both sectors), $\underline{c} = 1$ (subsistence consumption level), and $\rho = 0.6$ (minimum size requirement in horn production). Our choice of μ ensures that fertility converges back to its maximum level, π, when p.c. income grows to 50% above subsistence. This is in line with the observation that English birth rates in early modern times were similar to Chinese ones, despite the fact that English wages were substantially higher.[33] The parameter ρ is chosen such that the horn technology

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[32]The kink in English peasant household income results from decreasing wages when women join the workforce. The surge in labor supply when the horn technology becomes available leads to a redistribution of overall income from peasants to the landlord (see the left panel of Figure 3).

[33]According to Broadberry and Gupta (2006), Chinese grain-equivalent wages were 87% of English ones by 1550-1649, and fell to 38% in 1750-1849. The difference in silver wages – providing a better basis for comparison because they also consider traded

becomes feasible close to the subsistence level. We refer to subsistence income in England as the level during the early 14th century famine, when few horn products were consumed (see Table 4).

The orders of magnitude implied by this calibration can be seen in Figure 5. Birth rates fall by 1/3 for a close-to-subsistence income because of EMP. This is similar in magnitude to the numbers provided by Clark (2007). In addition to the downward-shift, birth rates also become upward-sloping in p.c. income. The income elasticity of fertility is positive. To pin down the long-run equilibrium, we need an the elasticity of mortality with respect to income. We use the figure from Kelly (2005), who estimates $\varphi_d = -0.55$ for early modern England. Finally, we choose $d_0 = 0.95\pi$ in (2), such that the pre-plague equilibrium involves close-to-subsistence income, as represented by E_L in Figure 5. Our stylized model leads to the new long-run equilibrium E_H after the plague, with peasant household income about 20% above the pre-plague level.

[Insert Figure 5 here]

Next, we turn to historical estimates for the elasticity of birth rates with respect to income, φ_b. We assume that birth rates are not responsive to income before the Black Death, so that $\varphi_b^{\text{before}} = 0$ below subsistence. After the plague, EMP makes birth rates responsive to income such that $\varphi_b^{\text{after}} = 1.41$, as estimated by Kelly (2005).[34] Figure 5 shows the results – given by the solid fertility line for the pre-plague period and by the dashed line for the post-plague period with EMP. Our stylized model performs remarkably well compared with the estimated relationship between p.c. income and fertility after the plague.[35] The exercise based on historical estimates of φ_b delivers an equilibrium E_H'. It corresponds to an impact of EMP on English p.c. income in the range of 30%. This is broadly similar – if slightly larger – than our model prediction. Our findings underline the importance of fertility restriction for increasing living standards in early modern Europe. At the same time, it is clear that EMP alone cannot account for all of the European (English) lead in terms of per capita income in 1700. Additional factors may include a different mortality regime, as well as (to a limited extent) technological change. We examine the contributions of these factors in (Voigtländer and Voth, 2008) in detail.

5 Conclusion

Why did Europe evolve a unique socio-economic system that reduced fertility through delayed marriage? We trace the origins of the European Marriage Pattern to the period after the Black Death. In our model, fertility restriction emerges as an indirect consequence of high land-labor ratios after 1348-50, which favored land-intensive pastoral production. Wages were exceptionally high. During this 'golden age of European labor,' workmen's diets became abundant in dairy and meat. Agricultural production switched 'from corn

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goods – was even larger. Broadberry and Gupta calculate that Chinese silver wages fell from 39% of the English level to a mere 15% over the same period.

[34]The equation $b = b_0 \left(\bar{C}_p / \underline{c} \right)^{\varphi_b}$ determines birth rates as a function of peasant household income, C_p. We choose $b_0^{\text{before}} = \pi$ and $b_0^{\text{after}} = 2/3\pi$, such that birth rates drop by 1/3 at the onset of EMP.

[35]This refers to the *slope* of the fertility schedule. The *drop* of fertility at the onset of EMP is a direct result of our calibration of π and $\underline{b}$.

to horn' (Campbell, 2000), with large increases in the number of cattle kept for meat and milk, and of sheep for mutton and wool.

The rise of livestock farming went hand-in-hand with a strengthening of women's economic role. Since most tasks in husbandry were not particularly strenuous, female labor could easily be used. After the Black Death, when wages were high, owners of large estates began to substitute arable farming, with its high demand for adult male labor, for husbandry, which required less labor, some of which could be supplied by women. They did so in order to economize on expensive male wages, and to seize the opportunities arising from the positive demand shock for meat, milk, and wool.

Women mainly worked on farms as servants in husbandry, milking cows and shepherding flocks of sheep. Working as a servants involved a switch from the parental household to the one of the lord. Marriage was not allowed. By working as servants for a few years, women could earn and save, increasing their chances of a better match in the marriage market. Because the Black Death changed the pattern of production and raised the demand for female labor, it also helped to reduce fertility rates, by raising the age at first marriage. We thus explain the concurrent emergence of late marriage, higher incomes, low fertility, and an agricultural system that used and produced unusually large numbers of farm animals.[36]

Thus, even in a Malthusian world, the 'iron law of wages' need not hold. If death schedules or birth schedules change, incomes can increase substantially. The equilibrating forces in such a world may still be 'Malthusian,' but they need not lead incomes back to the *same* equilibrium point.[37] We argue that changes in European fertility behavior were important for the persistence of high per capita incomes before 1800. In particular, fertility restriction through the 'European Marriage Pattern' allowed Europeans to avoid the worst consequences of high fertility in other parts of the world.

China was subject to a similar plague shock as Europe. Nonetheless, China did not develop a system of fertility restriction through late marriage. Marriage remained universal, and occurred early. We argue that this a consequence of the high productivity of land in Chinese agriculture. Rice paddy agriculture was highly productive; output per acre in China was high. This turned out to be a mixed blessing. High land productivity acted as a barrier to adopting land-using and labor-saving technologies such as cattle farming. In comparative perspective, it thus becomes clear that one of the weaknesses of the European agricultural system – low land productivity – led to lower fertility in Europe after the Black Death. By helping to stabilize incomes at a higher level by 1700, EMP may well have laid some of the foundations for Europe's early transition to self-sustaining growth (Voigtländer and Voth, 2006).

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[36]The mechanism is closest in spirit to the one proposed by Schultz (1985), who offered a similar explanation for fertility decline in 19th century Sweden.

[37]Mokyr and Voth (2009) distinguish between a weak and a strong form of the Malthusian model, where the former is subject to the same equilibrating forces, and the latter implies the 'iron law of wages.'

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Figure 1: Age at First Marriage and Marriage Seasonality
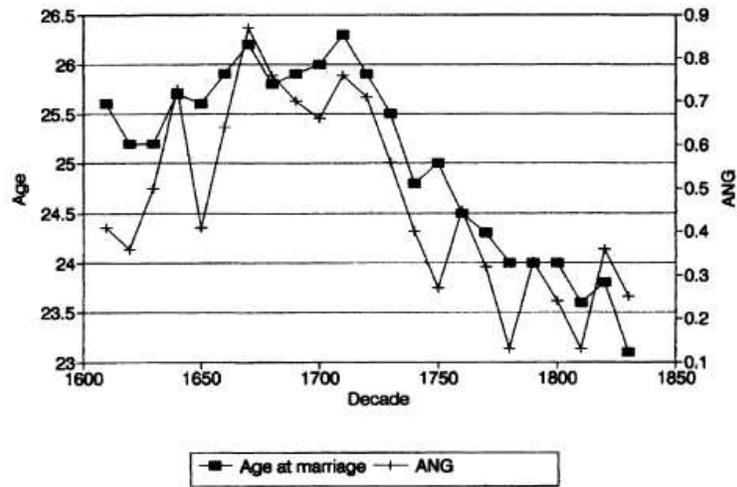
Source: Kussmaul (1981). ANG measures the relative strength of spring-to-fall marriage seasonality. Servants in pastoral agriculture typically married after the lambing season, spring. Workers in grain production married after the harvest in fall. Thus ANG shows the extent to which a marriage pattern is pastoral; high ANG means many servants working in the animal-producing sector. As employment in pastoral agriculture declines, the age at first marriage for women also falls sharply.
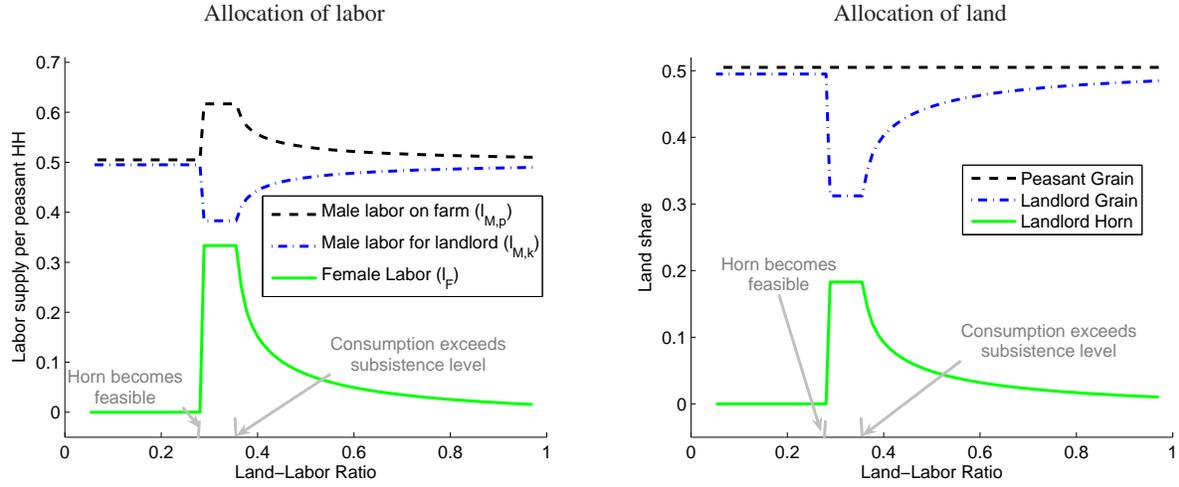
Figure 2: Static Equilibrium

Allocation of labor

Allocation of land

Figure 3: Income shares and fertility
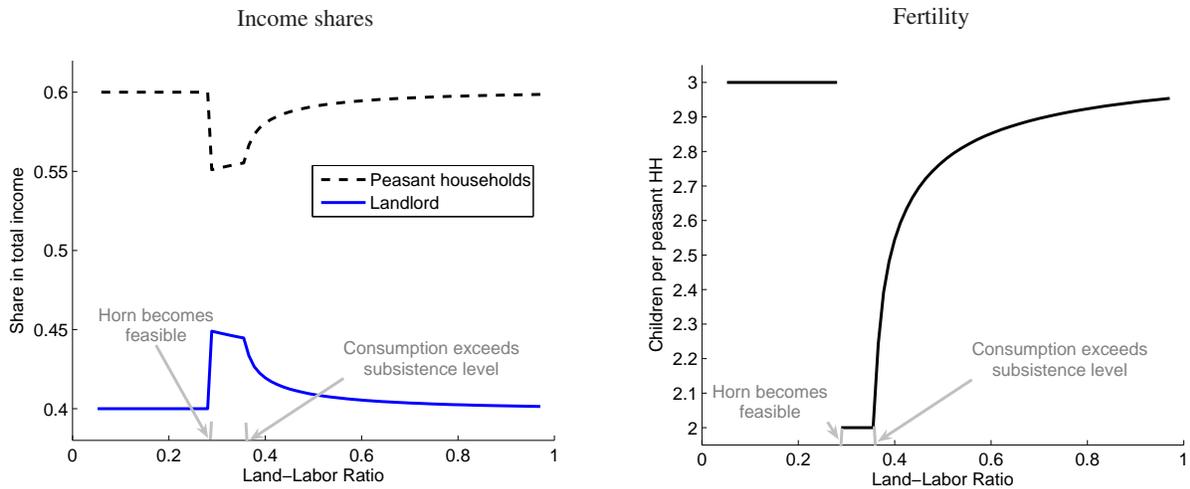
Income shares

Fertility

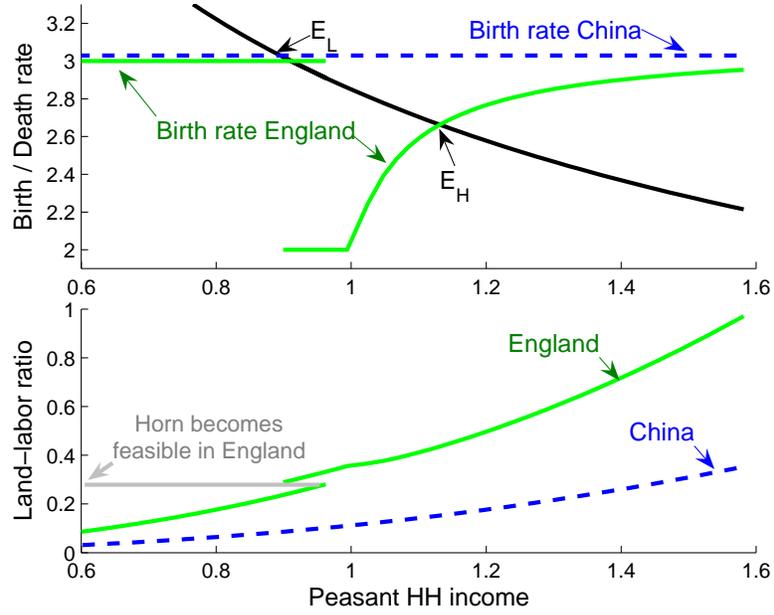Figure 4: Long-run equilibria in England and China

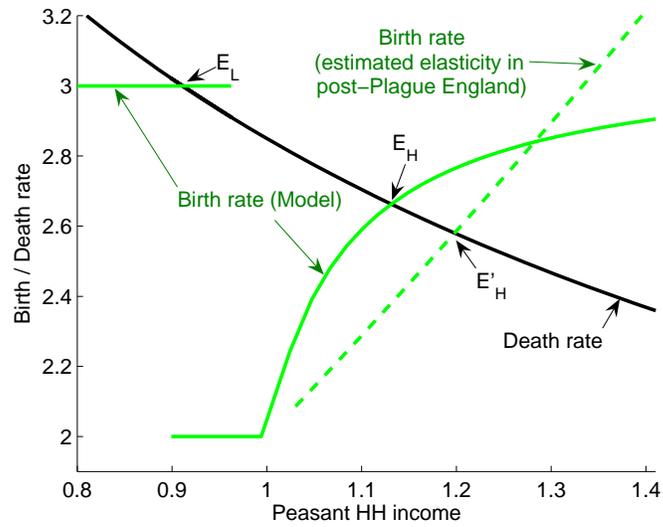Figure 5: EMP's impact on p.c. income in England

Table 1: Age of marriage and marital fertility in seventeenth century Europe

	Average Age of Women at First Marriage	Cumulative Marital Fertility (20-44)
England	25	7.6
France	24.6	9
Belgium	25	8.9
Germany	26.4	8.1
Scandinavia	26.7	8.3
Switzerland	-	9.3

Source: Flinn (1981). *Note*: Cumulative marital fertility = number of live births per married women married aged 20 to 44.

Table 2: Marital fertility rates (births per year and woman)

Age	Hutterite	Western Europe before 1800	China
20-24	0.55	0.45	0.27
25-29	0.502	0.43	0.25
30-34	0.447	0.37	0.22
35-39	0.406	0.3	0.18
40-44	0.222	0.18	0.12

Source: Clark (2007).

Table 3: Average farm size in England, China, and the Yangzi delta 1300-1850 (acres)

Year	1279	c.1400	c.1600	c.1700	1750	c.1800	1850
England	13.9		72	75		151	
China		4.2	3.4				2.5
Big Yangzi delta		3.75	1.875	1.875	1.25	1.16	1.04
Small Yangzi delta		2.89				1.04	

Source: Brenner and Isett (2002). English figures are from Allen (1992).

Table 4: Agricultural output before and after the Black Death

| | Output per head of population | | | | | |
	Milk (gallons)	Beef (lb)	Veal (lb)	Mutton (lb)	Pork (lb)	Wool (lb)
1265	77	29	3	62	32	17
1348	55	20	3	98	13	24
1550	137	46	7	141	50	26
1700	281	89	16	189	98	40
Ratio 1550/1348	2.5	2.3	2.8	1.4	3.8	1.1

Source: Apostolides et al. (2008)