How the West 'Invented' Fertility Restriction*

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December 2012

Abstract

We analyze the rise of the first socio-economic institution in history that limited fertility – long before the Demographic Transition. The "European Marriage Pattern" (EMP) raised the marriage age of women and ensured that many remained celibate, thereby reducing childbirths by up to one third between the 14th and 18th century. To explain the rise of EMP we build a two-sector model of agricultural production – grain and livestock. Women have a comparative advantage in the latter because plow agriculture requires physical strength. After the Black Death in 1348-50, land abundance triggered a shift towards the land-intensive pastoral sector, improving female employment prospects. Because women working in animal husbandry had to remain unmarried, more farm service spelled later marriages. The resulting reduction in fertility led to a new Malthusian steady state with lower population pressure and higher wages. The model can thus help to explain the divergence in income per capita between Europe and Asia long before the Industrial Revolution. Using detailed data from England after 1290, we provide strong evidence for our mechanism. Where pastoral agriculture dominated, more women worked as servants, and marriage occurred markedly later. Overall, we estimate that pastoral farming raised female ages at first marriage by more than 4 years.

JEL: E27, N13, N33, O14, O41

Keywords: Fertility, Great Divergence, Demographic Regime, Long-Run Growth

*We would like to thank the editor, Marianne Bertrand, and four anonymous referees, as well as Stefania Albanesi, Quamrul Ashraf, Francesco Caselli, Matteo Cervellati, Hal Cole, David de la Croix, Matthias Doepke, Ruben Durante, Raquel Fernández, Alessandra Fogli, Jesus Fernandez-Villaverde, Oded Galor, Jeremy Greenwood, Avner Greif, Nezih Guner, Sebnem Kalemli-Ozcan, Dirk Krueger, Naomi Lamoreaux, Oksana Leukhina, Kiminori Matsuyama, Joel Mokyr, Nathan Nunn, Víctor Ríos-Rull, David Stromberg, Michèle Tertilt, Jaume Ventura, Dietrich Vollrath, David Weil, and Fabrizio Zilibotti for helpful comments and suggestions. Seminar audiences at EEA-ESEM, NYU, Sciences Po, Stanford SITE, UCLA, UC Louvain, UPF, U Houston, U Penn, U Washington, and Warwick offered helpful advice. This paper is produced as part of the project Historical Patterns of Development and Underdevelopment: Origins and Persistence of the Great Divergence (HI-POD), a Collaborative Project funded by the European Commission's Seventh Research Framework Programme, Contract number 225342. Voigtländer: UCLA Anderson School of Management, 110 Westwood Plaza, Los Angeles, CA 90095. Email: nico.v@anderson.ucla.edu. Voth: Department of Economics, Universitat Pompeu Fabra, c/Ramon Trias Fargas 25-27, E-08005 Barcelona, Spain. Email: jvoth@crei.cat.

1 Introduction

Technology advanced for millennia before economic growth became rapid and per capita incomes increased significantly. Fertility control allowed a transition from "Malthus to Solow" to occur. In many models of long-run growth, the demographic transition is a necessary ingredient for self-sustaining growth. It allows productivity increases to translate into higher incomes instead of a larger population (Jones, 2001; Galor and Weil, 2000). Historically, European incomes per capita only began to grow once fertility had fallen significantly. The same is true in the 20th century: No developing country (except for oil producers) has attained medium income levels without going through a fertility transition beforehand (Chesnais, 1992; Chenery, Syrquin, and Elkington, 1975).

In contrast to the rest of the world, Europeans began to limit their fertility long before the onset of modern growth. As early as the 14th century, a "European Marriage Pattern" (Hajnal, 1965) had emerged which combined late marriage for women with a significant share of women never marrying. West of a line from St Petersburg to Trieste, where the European Marriage Pattern (EMP) was prevalent, Europeans avoided 25-40% of all possible births. The average female age at first marriage was 25 and 26.4 in England and Germany, respectively, in the 17th century.[1]

How did such a unique, early, and strong form of fertility limitation arise? The demographic history literature has focused on documenting EMP's key features – the age at first marriage, the percentage not marrying – and the areas where it came to dominate (Hajnal, 1965).[2] Much less attention has been paid to the reasons why Europeans "invented" fertility limitation. Earlier contributions have emphasized the importance of "girl power" (the ability of women to work outside the household and to decide whom to marry). This originated in the Catholic doctrine of mutual consent that evolved from the 9th century onwards (de Moor and van Zanden, 2010).[3] However, despite earlier antecedents (Hallam, 1985), there is a consensus that EMP only became fully developed after the Black Death in 1348-50 (Herlihy, 1997; Hajnal, 1965). Christian religious doctrine is therefore necessary but not sufficient to explain the timing and scale of the rise of EMP.

In this paper, we argue that the Black Death contributed crucially to the rise of fertility limitation in Europe. By killing between a third and half of the European population, it raised land-labor ratios. Land abundance favored the land-intensive sector – animal husbandry. Because plow agriculture requires physical strength, women have a comparative advantage in livestock farming (Alesina, Giuliano, and Nunn, 2011). Hence, after the Black Death, female employment opportunities improved. Working in husbandry mainly took the form of farm service – a contract that required year-round labor services in exchange for money, room, and board. As a condition of employment, all servants had to remain celibate – pregnancy and

[1] Similarly late marriages have only been registered again from the 1990s onwards, when the respective figures were 25.1 and 26.5 (UK-ONS, 2011; Flinn, 1981).

[2] For example, EMP was more common in cultures where newly married couples set up their own households ("neo-locality"). This is in contrast to the tendency of newly-weds elsewhere to live with the parents of the groom (Hajnal, 1982).

[3] De Moor and van Zanden also emphasize limited parental authority, neolocality, and the importance of urban labor markets. We discuss related literature in more detail below.

marriage resulted in termination of employment. Because many more women began to work in the booming pastoral sector after 1350, marriage ages increased. This lowered fertility in the aggregate. In a Malthusian world, there were second-round effects: Lower fertility reduced population pressure, ensuring that per capita output never returned to pre-plague levels.

We build a simple Malthusian two-sector model with endogenous marriage decisions to explain the emergence of EMP. Land is in fixed supply; as population increases, incomes decline. There are two types of agricultural output, "horn" (pastoral) and "grain" (arable). Both are produced with Cobb-Douglas technology using land and labor. The only difference are the factor shares, with land having a higher weight in pastoral production. All the land in our model is owned by the lord, and is either rented out to farmers (for grain production) or operated directly (for livestock farming). Women make all important decisions. They trade off income (from wages in the horn sector) against having children (while working on the family farm in grain production). Before the Black Death, land-labor ratios are low; land is relatively dear, and labor is cheap. Grain dominates the diet. Women marry early and work alongside men in family-operated arable agriculture. By killing one third of the population, the Black Death raises land-labor ratios and thus wages. Land abundance favors the land-intensive livestock sector. In addition, consumption shifts from grain towards 'luxury' goods like meat, dairy, and wool. As a result, pastoral production expands, raising female employment opportunities outside the peasant household. Marriages are postponed, and childbearing is curtailed. Low fertility in turn keeps land-labor ratios relatively high, stabilizing incomes.

The empirical section systematically confronts the model's predictions with data, using 14C-19C England as a case study. Our theoretical setup implies that where women were employed in large numbers in agriculture, milking cows and tending sheep, marriage should occur late; and where arable agriculture dominated, marriage ages should be lower. Panel data on age at first marriage in early modern England (based on family reconstitutions from the Cambridge Group of Population Studies) confirm these predictions . An IV-strategy allows us to sidestep issues of causality, using data on weather conditions by county. We also analyze poll tax records from 1377 and 1381, documenting that these patterns were already visible shortly after the plague. In addition, as pastoral farming spread after the Black Death, many villages in England were abandoned. We use this indicator to show that in areas where cultivation switched from grain to pasture, women on average married later. Finally, we demonstrate that pastoral marriage patterns are a reliable predictor of late marriage. Overall, we estimate that without pastoral production, marriages in early modern England would have occurred more than 4 years earlier.

Our model has implications for the "First Divergence" – Europe's precocious rise to riches in the centuries before technological change became rapid. European per capita incomes increased to levels far above subsistence (and ahead of other regions of the world) long before the Industrial Revolution. In addition, North-Western Europe grew much faster than Southern and Eastern Europe (Maddison, 1995; Acemoglu, Johnson, and Robinson, 2005). While several other factors – high European death rates, the rise of Atlantic trade, and accelerating technological progress – probably played a role (Voigtländer and Voth, 2013; Acemoglu et al., 2005; Mokyr, 1990), fertility limitation was arguably one powerful contributor to greater riches in a Malthusian setting (Wrigley, 1988; Ashraf and Galor, 2011). Figure 1 illustrates how income and fertility interact in a Malthusian economy. Death rates decline in p.c. income. Fertility depends on the demographic regime. Without EMP (rest of the world – ROW), fertility is constant and high.[4] In Europe, it is lower on average and responds to economic conditions. The latter implies an economic "shock absorber" mechanism: Hard times spell late marriages and thus low fertility, which helps to stabilize incomes. The intersection of birth and death schedules defines the steady state(s), where population and income are constant. In the absence of fertility restriction, the economy is in a low-income steady state (S^{ROW}). EMP helped Europe to transition to a more benign steady state(S^{Europe}), combining high incomes with low fertility.[5] Areas with traditional fertility regimes (such as China) have only one steady state, combining high fertility and low per capita incomes.

[Insert Figure 1 here]

A natural implication of our model is that land and labor productivity differences are key for explaining where fertility limitation will emerge. In areas where grain sector productivity is *high*, EMP will not develop. We discuss this for the case of China, where grain (rice) productivity was about four times higher than in Europe. Similarly, in Eastern Europe, where grain production was highly efficient and the Black Death had a limited impact, EMP did not emerge.

Related work on the origins of EMP includes Devolder (1999), who emphasizes the introduction of short-term leaseholds as a factor behind the rise of EMP. Foreman-Peck (2009) builds a model in which European fertility restriction follows from changes in mortality patterns. De Moor and van Zanden (2010) emphasize the role of Christianity because it requires an act of the will for marriage to be valid. They also argue that neolocality – the formation of a new household set up away from the parental home – and the rise of a landless proletariat, combined with access to urban labor markets, encouraged women to 'take time to choose' their marriage partners. Finally, Mitterauer (2003) argues that feudal land holding patterns were crucial for the emergence of EMP, favoring inheritance systems that went hand in hand with the formation of nuclear households.

Our paper forms part of a broader body of work on the causes of fertility change. Demographers have typically emphasized the fall in mortality (Chesnais, 1992). While intuitive, there is scant empirical support that lower child mortality reduced fertility (Galor, 2005). Rising incomes are a leading alternative interpretation (Becker, 1981). At the same time, as the Princeton European Fertility Project (Coale and Watkins, 1986) demonstrated, the diffusion of fertility limitation in the 19th century is poorly predicted by economic factors.[6] There is also work on cultural change as a main drive of fertility restriction (Coale and Watkins, 1986), as well as the old-age security hypothesis (Neher, 1971; Boldrin and Jones, 2002). One important approach emphasizes rising returns to investments in child quality (Becker and Lewis, 1973; Galor and Weil,

[4] This reflects a wide consensus amongst demographers – going back to Malthus' (1798) observation that outside of Europe, fertility did not respond to economic conditions, so that the "positive check" (of rising death rates) governed population dynamics.

[5] Other factors, in particular increasing death rates due to epidemics and warfare, had a similar effect as low birth rates (Voigtländer and Voth, 2013). This reinforced the transition to a high-income Malthusian steady state.

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

1999).[7] An alternative strand in the literature emphasizes changes in female wages (Becker, 1960; Mincer, 1963; Schultz, 1985). 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 (Galor and Weil, 1996).[8]

Relative to this literature, we make several contributions. We present the first rigorous model explaining the rise of EMP as a result of utility-maximizing behavior, following a large positive shock to income. In our theory, fertility restriction arises without a role for human capital, in contrast to models in the spirit of Becker and Lewis (1973). Our approach emphasizes women's opportunity cost, as determined by changes in the structure of agricultural production following the Black Death. In effect, we argue that a new socioeconomic institution emerges in response to a sharp change in factor prices. We also provide empirical support for each step of the proposed mechanism, using detailed county-level data for England during the late medieval and early modern period. Finally, we assess the overall contribution of pastoralism to delayed marriage quantitatively.

Several papers in the unified growth tradition relate to our work. In Galor and Weil (1996) female labor is more complementary to capital than male labor; capital accumulation raises female wages and lowers fertility. In our model, land plays a similar role. Because women have a comparative advantage in the land-intensive horn sector, their wages rise with the abundance of land, and fertility falls. Vollrath (2011) also builds a two-sector model in which lower labor intensity can lead to greater riches in the long run.[9] Unified Growth Theory seeks a single explanation of the transition from 'Malthusian stagnation' to self-sustaining, rapid growth (Galor, 2005; Hansen and Prescott, 2002; Galor and Moav, 2002). Papers in this literature typically assume that as growth takes off, the return to human capital rises, which then lowers fertility (Lucas, 2002; Galor and Weil, 2000).[10] The unit of analysis is the world as a whole. Instead, we focus on cross-sectional differences, examining factors that led to Europe's precocious rise to riches. We emphasize the potential for fertility to change substantially prior to the "take-off," and without changes in the return to human capital. Finally, two other features distinguish our model from existing ones. First, for very low land-labor ratios, the horn technology is not economically viable because women's wages in horn are below their counterpart in grain production. Thus, the mechanism leading to fertility decline does not operate in a land-scarce economy. Second, married couples cannot control their fertility. Instead, the number of children results from a tradeoff between female work time away from home and married life with home production. This reflects the historical fact that effective contraception was unavailable in early modern times; delayed marriage (and fewer women marrying) was the only way to reduce fertility.

We are not the first to argue that the Black Death caused important changes in the European economy.

[7] 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, which also changed the cost of investment in child quality (Doepke, 2004; Doepke and Zilibotti, 2008).

[8] Doepke, Hazan, and Maoz (2012) examine changes in relative wages for women after World War II and argue that one-off negative shocks to the value of female labor increases in fertility. On the same issue, Greenwood, Seshadri, and Vandenbroucke (2005) argue that technological advances in the household sector lowered the cost of children and contributed to the baby boom.

[9] Vollrath shows that high labor intensity in agriculture can lead to higher fertility and therefore lower p.c. income. This is compatible with our argument, where pastoral agriculture (with low labor intensity) was central for Europe's fertility restriction.

[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.

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. Epstein (2000) argued that institutional constraints on growth were removed by the plague. Herlihy (1997) speculated that the emergence of fertility restriction 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. Finally, Pamuk (2007) surveys the evidence that the Black Death ushered in a transformation of the European economy, reducing and then reversing the income gap between Southern and Northwestern Europe.[11]

We proceed as follows: Section 2 discusses the historical background. Section 3 presents our model, and section 4 presents our empirical analysis. In section 5, we focus on several international comparisons. Section 6 concludes.

2 Historical Background

In this section, we summarize the existing state of historical knowledge about the rise and fall of fertility restriction in early modern Europe.

Two main factors curtailed fertility under EMP – late female marriage, and a high percentage of women never marrying. In the Roman Empire, age at first marriage was 12-15 for pagan girls, and somewhat higher for Christian girls. Herlihy (1985) estimates that by 500 AD, the average marriage age for women in Western Europe was 18-19 years. During the Middle Ages, this number may have been slightly higher than in Roman times. For a group of medieval Lincolnshire villages, Hallam (1985) estimated ages at first marriage for women of around 20.[12] Among the English nobility, marriage at age 17 was common in the 12th century. Numbers for fourteenth-century Tuscany are similar (Herlihy, 1985). Central features of EMP – a marriage age above the biological age of fertility, and some women never marrying – probably originated in some areas before the 14th century (Laslett and Wall, 1972). However, the European Marriage Pattern, with the age at first marriage postponed to 25 or beyond, only emerged after the Black Death, and the pattern was strongest in Northwestern Europe (Hajnal, 1965, 1982). For English women, the age at first marriage in the early modern period was 25 years; 17.5% never married. Scandinavians married even later. Table 1 gives an overview:

[Insert Table 1 here]

Within marriage, fertility was largely unconstrained. To show this, Clark (2007) compares Western European marital fertility with contemporaneous levels of Hutterites (a modern-day Canadian sect that rejects

[11] The nature of the Malthusian world before 1800 is examined *inter alia* in Wrigley, Davies, Oeppen, and Schofield (1997), Kremer (1993), Clark (2007), and Ashraf and Galor (2010). The extent to which negative shocks raised death rates and lowered fertility rates is discussed by Anderson and Lee (2002), Galloway (1988), Crafts and Mills (2008), and Kelly and Ó Grada (2008).

[12] The percentage of females never married needs to be established through family reconstitutions, which track cohorts over the entire life cycle. For the period before1500, these are not available. Instead, one can look at the proportion of women unmarried at a particular point in time. Because some women will eventually find husbands and have children, this constitutes 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. The proportion of unmarried women was probably much less. In the 9th century, in Villeneuve-Saint-Georges, up to 12% of adults had never married (Hallam, 1985).

birth control). He finds that both are very similar, implying that fertility within marriage in early modern Europe was probably close to the biological maximum (see Appendix B.4 for more detail).

Northwestern Europe in particular evolved a 'low pressure demographic regime' (Wrigley et al., 1997). Negative economic shocks were largely absorbed through Malthus's preventive check (lower nuptiality), rather than the positive check (death rates surging). As economic conditions worsened, fertility declined. 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). This helped to reduce the downward pressure on living standards.

Late marriage was arguably voluntary: Children were often independent from their parents by their teenage years, and became fully legally independent at age 21 – several years before the average age at first marriage. The law did not ban early marriages. In England, the legal age for marriage was 12 for women, 14 for men (Clark, 2007). While the authorities hoped to raise age at marriage – through apprenticeships, for example – there were many 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 be as high as 40% (Wrigley and Schofield, 1981).

Apprenticeships and service in agriculture played an important role in postponing marriage. A significant part of young men and women were thus employed, especially in Northwestern Europe; in England, up to half of all boys and girls aged 15-25 worked as servants (Kussmaul, 1981).[13] After 1349, landlords increasingly hired agricultural servants to work on the larger farms (Kussmaul, 1981). The *Museum Rusticum*, an 18th century periodical on rural affairs, called service "a covenanted state of celibacy." Marriage typically implied an immediate termination of service. Kussmaul (1981) calculates that 65% of servants married immediately before or after the end of their contracts. Celibacy was both a convention and a technological requirement. Pastoralism has fairly steady labor requirements throughout the year. This makes it attractive to employ servants year-round, instead of hiring agricultural laborers on daily wages. Marriage and childbearing reduces female labor supply, and makes it more variable. As such, it would have been incompatible with the labor requirements in pastoral agriculture. As the English philosopher David Hume put it in 1742: "All masters ... admit not by any means the marrying of the female, who are then supposed altogether incapacitated for their service" (Hume, 1854, p. 430). Servants were entitled to room and board in exchange for labor services. Housing married maids and their offspring would have involved a heavy additional expense. The system also had advantages for the servants. 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."

EMP in England declined in the second half of the eighteenth century. After the 1730s, mean ages at first marriage trended down for both men and women. A number of factors reduced female employment

[13] For example, Hajnal (1982) gives the share of women aged 20-24 working as servants in the early modern period as 51 percent in Denmark, 44 in Iceland, 36 in Holland, 40 in England, and 33 (both sexes) in Norway

opportunities in husbandry. As grain prices rose in the 18th century relative to the price of meat and dairy products, pastoral production declined (Snell, 1981). In addition, economic change undermined the institution of farm service for young women. Cottage shop manufacturing offered a chance to earn a living while having children. Female earnings opportunities outside of animal husbandry improved; thus women could marry earlier, and still earn the same. By the 1830s, age at marriage had fallen from 26 for women (and 27 for men) in 1700 to 23 (and 25, respectively). Population growth accelerated from zero to 1.75% per annum (Wrigley et al., 1997). Using Kussmaul's (1990) marriage seasonality measure as a proxy for farm service, Schellekens (1997, 2001) shows that the decline of service in husbandry is a major explanation for the rise in nuptiality. The decline of England's low fertility regime was thus brought on by the same factors that led to its rise during the early modern period – changes in the opportunity cost of female labor, as determined by demand conditions in husbandry.

3 Model

This section presents a simple Malthusian model with endogenous labor supply and marriage decisions. The economy is composed of a mass of N female and N male peasants who work, consume, and procreate.[14] People live for two periods, childhood and adulthood. Children do not work or consume. For simplicity, we assume that adulthood and childhood are of equal length and that wages are the only source of income for peasants. There are two agricultural sectors of production, grain and horn (e.g., meat, milk, and wool). All men are equal; they rent land on which they operate small grain farms. Women differ with respect to physical strength, and thus in terms of their productivity in the strenuous grain sector.[15] Physical strength matters less for pastoral production, so that all women are equally suited for the horn sector. Only unmarried women can work in horn.

When they become adults, women decide when to marry, maximizing their expected utility. Before marriage, they do not have children. During marriage, there is no birth control and children arrive with frequency π. Delaying marriage is thus the only 'contraceptive technology.' Women can earn a wage premium in pastoral production as long as they are unmarried. This implies a tradeoff between income and marriage, which endogenously determines the age at marriage and thus fertility. We define the European Marriage Pattern as follows:

Definition 1. *Let $\bar{b}$ be the birth rate when women spend all their adult life married. Then EMP is a demographic regime that involves (i) $b < \bar{b}$ because women remain unmarried throughout a part of adulthood, and (ii) b increases in p.c. income.*

[14] We call all economic agents that are not large landowners 'peasants' (landholders subsisting by working a small plot). Note that in England, there were no peasants in the strict sense of the word. Instead, most tenant farms were relatively large (as we discuss in section 2), and were often operated with hired labor. We use the 'peasant' terminology for simplicity. In our model, it merely implies that large landowners have an advantage producing pastoral products compared to 'peasants.'

[15] In our model, female strength differences have very similar effects to other forms of heterogeneity (such as TFP differences in arable farming, or region-specific advantages in pastoral land suitability). While heterogeneity in female strength is not crucial for our main result – the emergence of EMP – it adds historical realism and ensures that aggregate fertility is a smooth function of per-capita incomes.

The economy is Malthusian – a steady state is determined by the intersection of the mortality and fertility schedules. The former declines in consumption, while the latter depends on the demographic regime. In the absence of EMP, the fertility schedule is flat, as shown in Figure 1. Without EMP, the economy is in a steady state with high, constant birth rates and low per-capita income (S^{ROW} in Figure 1). With EMP, the birth schedule shifts downward due to delayed marriage (property (i) of EMP). In addition, an income effect causes birth rates to increase with wages (property (ii)). The new steady state has lower birth rates, combined with higher per capita incomes. We argue that the Black Death contributed to the transition from a low- to a high-income steady state in Western Europe after the Black Death. Our mechanism can explain the slow rise of population levels after 1349, and the persistence of higher output per capita in Europe. We also discuss productivity characteristics that favor the emergence of EMP in Europe as compared to China.

In the following, we describe the central components of the model. We first build the intuition for the mechanism by focusing on the labor supply side, and then derive the Malthusian equilibria, accounting for the fact that livestock products were "luxury goods."

3.1 Peasant Families: Preferences, Labor Supply, and Fertility

Adult peasants live for one period. All men are equal, while women differ in their physical strength. Female strength relative to men $\rho \in (0,1)$ is randomly distributed, as given by the probability density function $f(\cdot)$. Hereafter, we use the subscript i to refer to a particular strength draw, ρ_i, and thus to the different 'types' of women. Because EMP is closely associated with women deciding when to marry (de Moor and van Zanden, 2010), we focus on the female optimization problem. In the spirit of Galor and Weil (1996), women draw utility from consumption and children:

$$u(C_i, b_i) = (1-\mu)v(C_i) + \mu \ln(b_i - \underline{b}), \tag{1}$$

where $v(C_i)$ denotes utility from a consumption composite throughout adult life, b_i is the number of children (with a lower bound $\underline{b}$), and μ represents the relative importance of children vs. consumption in women's utility. There are no investments or bequests to children – all income is spent on consumption during adult life. We assume that male strength is homogeneous, and that men's consumption preferences are identical to those of women. When women decide to marry, they all receive the same (random) match as a husband. All relevant decisions in the model are thus made by women. Consumption utility throughout the adult period is given by:[16]

$$v(C_i) = \begin{cases} \ln(C_i - \underline{c} + \epsilon) & \text{if } C_i > \underline{c} \\ \\ (C_i - \underline{c})/\epsilon + \ln(\epsilon) & \text{if } C_i \leq \underline{c} \end{cases} \tag{2}$$

[16]Consumption utility is derived from total income throughout adult life. This implicitly assumes that i) women do not discount within the adult period and ii) consumption at different points throughout adult life is perfectly substitutable. One could split the adult period into an unmarried and a married part with different consumption levels. This would add realism (and complexity), but not change our qualitative results.

where ϵ is a positive number close to zero. This specification ensures that v and v' are continuous and that the marginal utility is a large positive number whenever $C_i \leq \underline{c}$.[17] Whether or not income is above the reference level $\underline{c}$ plays a central role in our model. We think of $\underline{c}$ as the per-capita consumption that fulfills basic needs, but does not yet include any luxury items (such as meat products). Below $\underline{c}$, the marginal utility of consumption is high, and it falls rapidly as consumption exceeds $\underline{c}$.[18] This setup delivers an income effect: Fertility rises when consumption grows beyond $\underline{c}$.[19] Consumption utility is drawn from two goods: Grain ($c_{i,g}$) and horn products ($c_{i,h}$). We use grain as the numeraire; the price of horn goods is denoted by p_h. To focus on the main mechanism, we take p_h as given, only assuming that horn is not an inferior good so that p_h is non-decreasing in income. In section 3.6 below we introduce non-homothetic preferences where the expenditure share for horn products rises with income above the reference level $\underline{c}$.

Male and female peasants each provide one unit of labor during adulthood. Men earn the uniform male wage rate in grain production, w_{Mg}. Women split their labor supply between the horn and the grain sector. In line with the historical evidence on animal husbandry (section 2), marriage is not allowed for women working as servants in the horn sector. Women spend a share $l_{i,h}$ of their adult life in horn production, being unmarried and earning w_h. The remainder $1 - l_{i,h}$ is married life with work in grain production on the peasant farm.[20] A woman's marginal product in peasant grain production depends on her physical strength (relative to men) and is given by $w_{i,Fg} = \rho_i w_{Mg}$, with $\rho_i < 1$. Female income throughout the adult period is thus

$$I_i = w_h l_{i,h} + \rho_i w_{Mg}(1 - l_{i,h}) \ . \tag{3}$$

Female labor supply is determined by the trade-off between earnings in horn production (i.e., if $w_h > w_{i,Fg}$) and child rearing during marriage. While single, the probability of childbearing is zero. After marrying, husband and wife form a new household, and women work in grain production on the peasant farm. The share of adult lifetime married thus corresponds to female labor supply in the grain sector, $l_{i,Fg} = 1 - l_{i,h}$.[21] There is no contraception, and married couples produce π births per unit of time.[22] Consequently, the number of offspring for woman i is given by

$$b_i = \pi(1 - l_{i,h}) \tag{4}$$

[17] We use $\underline{c} = 1$, so that $\lim_{C_i \to \underline{c}} v(C_i) = \ln(\epsilon)$ and $\lim_{C_i \to \underline{c}} v'(C_i) = 1/\epsilon$ for convergence to $\underline{c}$ from above and below.

[18] The reference level $\underline{c}$ is thus similar to subsistence consumption, with one important difference: People do not starve below this level; they merely value consumption more because their basic material needs are unmet. This allows us to include the consumption range below $\underline{c}$ as an integral part of the model.

[19] The income effect is stronger the closer C_i is to $\underline{c}$. It is thus similar to the 'subsistence effect' that Jones (2001) integrates in the standard fertility framework (Barro and Becker, 1989). For very high income levels ($C_i >> \underline{c}$), our preferences behave as in the standard log-case (c.f. Galor and Weil, 1996) – further increases in income have no effect on birth rates.

[20] Because only women work in horn production, we do not need extra subscripts for male or female peasants; the subscript h is sufficient. Historically, men also worked in pastoral farming. Here we make the simplifying assumption that they only work in grain production on their rented farm land. What is important for our mechanism is that women work *relatively* more in horn.

[21] We implicitly assume that working in grain production is compatible with raising children.

[22] For simplicity, we treat π as a deterministic frequency, rather than as probability draws. In addition, we assume that child mortality does not directly influence birth rates. Thus, there is no role for precautionary children in our model.

Given ρ_i, w_{Mg}, and w_h, women maximize (1) subject to the consumption utility given by (2), their income (3), and the birth rate given by (4). In the absence of bequests and investments, the budget constraint holds with equality, i.e., $C_i = I_i$.[23] The female optimization problem is then

$$\max_{l_{i,h}} \{(1-\mu)\, v\,(I_i(l_{i,h})) \;+\; \mu \ln\left[\pi(1-l_{i,h}) - \underline{b}\right]\} \qquad (5)$$
$$s.t. \quad 0 \leq l_{i,h} \leq 1$$

When $w_h \leq w_{i,Fg}$ (i.e., labor in horn is not attractive for women of strength ρ_i), this simplifies to the corner solution $l_{i,h} = 0$. The interior solution to the female optimization problem is described in more detail below.

Finally, we describe mortality in our model. Death rates among adults are zero until a given period is over. Overall mortality is thus driven exclusively by child mortality.[24] The survival of children depends on average consumption. The death rate is given by

$$d = d_0 \;(\bar{c}^p/\underline{c})^{\varphi_d} \;, \qquad (6)$$

where $\varphi_d < 0$ is the elasticity of child mortality with respect to average per-capita consumption of peasants ($\bar{c}^p$), and d_0 is the death rate at the reference consumption level $\underline{c}$.[25] Consequently, mortality falls as p.c. income rises. Despite the fact that individuals cannot satisfy all their material needs below $\underline{c}$, there is no spike in mortality – the death rate increases continuously as $\bar{c}^p$ falls below $\underline{c}$. At the end of each period, parents die and surviving offspring form the next adult generation.

The optimization problem is static, which simplifies our analysis. This is similar to Jones (2001) and can be derived from a more general dynamic optimization problem under two assumptions that we make. 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 (6) that child mortality depends on average per-capita consumption. Since women take average consumption as given, child mortality does not interfere with their optimal labor supply decision. 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 (5).

3.2 The Landlord, Location of Production, and Technology

Both technologies – grain (g) and horn (h) – use land and labor as inputs. A landlord owns all land T, which is in fixed supply. He does not work. Peasants rent land T_g for grain production. On the remaining land $T_h = T - T_g$, the landlord operates large-scale horn production, hiring female workers and paying them

[23] For now, we use this simplified notation. In section 3.6 we introduce an appropriately defined aggregator function C_i of the two types of consumption goods.

[24] Historically, child mortality was the main driver of overall life expectancy.

[25] A historical justification for child mortality depending on average (rather than individual) income is that its main cause were diseases like diarrhea and typhus, whose spread depends on hygienic conditions (and therefore income) in the community.

their marginal product as wages.[26] We assume that the horn technology is only available to owners of large estates, i.e., to the landlord in our model. This is motivated by size differences between arable and pastoral farms (Campbell, 2000).[27]

The landlord does not work and does not derive utility from children; he is infinitely-lived. Therefore, he does not influence fertility directly. The landlord's only source of income are land rents, generated by charging the marginal product of land in the two sectors, r_g and r_h. He uses his income in each period to finance activities that are unrelated to agricultural production (e.g., building castles or engaging in warfare). Thus, his expenditure does not affect the relative demand for grain vs. horn products. The landlord maximizes rental income, allocating land optimally between the two sectors:

$$\max_{T_g} \{r_g T_g + r_h(T - T_g)\} \tag{7}$$

Horn output is produced according to:

$$Y_h = A_h L_h^{\alpha_h} T_h^{1-\alpha_h} , \tag{8}$$

where A_h denotes total factor productivity (TFP), T_h is land used for pastoral production, and L_h is total labor input in this sector. The grain technology is more labor-, and less land-intensive than horn production. This is represented by $\alpha_g > \alpha_h$ in the production function

$$Y_g = A_g \widehat{L}_g^{\alpha_g} T_g^{1-\alpha_g} , \tag{9}$$

where A_g and α_g are TFP and the labor share in grain production, respectively; T_g is land dedicated to grain, and $\widehat{L}_g$ denotes effective peasant grain-labor supply. The latter is given by:

$$\widehat{L}_g = L_{M,g} + \widehat{L}_{F,g} . \tag{10}$$

where $L_{M,g}$ and $\widehat{L}_{F,g}$ denote total male and *effective* female grain-labor input, respectively. While both types of labor are perfectly substitutable, men have a relative advantage compared to women because grain farming requires arduous physical labor, such as ploughing, threshing, and reaping. This is captured by the relative strength parameter $\rho_i < 1$ introduced above. Because there is a mass N of peasant households, grain labor supply can be expressed as $\widehat{L}_g = N \cdot \widehat{l}_g$. The lower case letter denotes the *average* effective grain

[26] Alternatively, we could assume that landlords manage the production on all their land, paying grain and horn workers their marginal product. The crucial assumption for our mechanism is that large-scale horn production requires female workers to remain celibate.

[27] A minimum land requirement for horn production would have similar implications for who produces horn. 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; peasants can only grow grain on the farm land that they rent.

labor supply by peasant households, which is equal to the sum of average male and female labor in grain:

$$\widehat{l}_g = l_{M,g} + \int_0^1 \rho_i \cdot l_{i,Fg}(\rho_i) f(\rho_i) d\rho_i = 1 + \int_0^1 \rho_i \cdot (1 - l_{i,h}(\rho_i))\, f(\rho_i) d\rho_i \,. \tag{11}$$

To derive the second equality, we used the fact that men work in grain throughout adulthood ($l_{M,g} = 1$), while women split their labor supply across the two sectors, $l_{i,Fg} + l_{i,h} = 1$. The integral in (11) is the average effective female labor supply in grain, across all strength types ρ_i. Note that $l_{i,h}(\rho_i)$ is the share of adult lifetime that a woman with strength ρ_i spends working in horn production, so that $\rho_i\,(1 - l_{i,h}(\rho_i))$ is her effective labor supply in grain. Correspondingly, the *average* horn labor supply per woman (and thus per peasant household) is given by $l_h = \int_0^1 l_{i,h}(\rho_i) f(\rho_i) d\rho_i$, while $L_h = N \cdot l_h$ is the total labor supply in horn.

Because peasants do not have access to the large-scale horn technology, production occurs as follows: Peasants grow grain on rented land, while the landlord engages in livestock farming on large demesnes. Peasant households (where the woman has strength ρ_i) rent land $t_g(\rho_i)$ for grain production. Thus, the average rented land per household is $t_g = \int_0^1 t_g(\rho_i) f(\rho_i) d\rho_i$. We normalize aggregate land by the mass of peasant households: $t = T/N$ so that average pastoral land per household is $t_h = t - t_g$. This completes the basic setup of our model. Next, we derive factor payments and show how land is allocated between grain and horn production. In addition, we examine the female labor supply decision.

3.3 Factor Payments and Allocation of Labor

When pastoral production occurs, the landlord pays a wage rate equal to the marginal product of labor in (8), taking the relative price of horn p_h as given:[28]

$$w_h = \alpha_h p_h A_h \left(\frac{T_h}{L_h}\right)^{1-\alpha_h} = \alpha_h p_h A_h \left(\frac{t_h}{l_h}\right)^{1-\alpha_h} \,. \tag{12}$$

Next, we turn to arable production. When growing grain on rented land, the marginal product of male labor follows from (9) and is given by

$$w_{Mg} = \alpha_g A_g \left(\frac{T_g}{\widehat{L}_g}\right)^{1-\alpha_g} = \alpha_g A_g \left(\frac{t_g}{\widehat{l}_g}\right)^{1-\alpha_g} \,. \tag{13}$$

The marginal product of a married woman in home grain production depends on her strength and is given by $w_{i,Fg} = \rho_i\, w_{Mg}$.

[28] Note that the ratio of pastoral land per household to the labor supply in horn per average peasant household, t_h/l_h, is equivalent to the aggregate land-labor ratio in horn, T_h/L_h. The same is true for the strength-adjusted land-labor ratio in grain production. In the interest of simplicity, we use the terminology 'land-labor ratio' in horn and grain in the following, whenever we refer to the ratios t_h/l_h or $t_g/\widehat{l}_g$

Peasant households pay the rental rate r_g, while the return to land in horn production is r_h, as given by:

$$r_g = (1-\alpha_g)A_g\left(\frac{\widehat{l}_g}{t_g}\right)^{\alpha_g} \quad , \quad r_h = (1-\alpha_h)p_h A_h\left(\frac{l_h}{t_h}\right)^{\alpha_h} \tag{14}$$

The landlord's optimal allocation of land according to equation (7) implies $r_g = r_h = r$. This yields:

$$\frac{t_h}{l_h} \;=\; \left(\frac{p_h A_h}{A_g}\,\frac{1-\alpha_h}{1-\alpha_g}\right)^{\frac{1}{\alpha_h}}\left(\frac{t_g}{\widehat{l}_g}\right)^{\frac{\alpha_g}{\alpha_h}} . \tag{15}$$

This equation says that the land-labor ratio in horn is proportional to its efficiency-adjusted counterpart in grain production, provided that both sectors operate. Land per unit of labor in horn relative to grain increases (i) in the TFP ratios – relatively more land is dedicated to the more productive technology, (ii) in the price of horn p_h, and (iii) in the land-intensity of horn relative to grain, as governed by α_h and α_g.

Much of our analysis relies on changes in the aggregate land-labor ratio t. With decreasing returns to labor in both sectors, larger t spells higher wages. The following proposition shows how sector-specific land-labor ratios change with their aggregate counterpart. The response of p_h to income (and thus, t) is important in this context. For now, we merely assume that $dp_h/dt \geq 0$ (horn is not an inferior good). In section 3.6 we explicitly model demand for the two goods.

Proposition 1. *If both technologies operate and the aggregate land-labor ratio $t = T/N$ grows, then the land-labor ratio in horn will also increase: $\frac{d(t_h/l_h)}{dt} > 0$.*

PROOF. If both technologies operate and average land per household t increases, factor market clearing implies that land-labor ratios must increase in at least one of the two sectors. First, suppose that $dp_h/dt = 0$. Then, following (15), $d(t_g/\widehat{l}_g)/dt$ and $d(t_h/l_h)/dt$ have the same sign. Consequently, both derivatives are strictly positive. Second, suppose that $dp_h/dt > 0$. In this case following (15), if $d(t_g/\widehat{l}_g)/dt > 0$, then $d(t_h/l_h)/dt > 0$. On the other hand, if $d(t_g/\widehat{l}_g)/dt \leq 0$, then $d(t_h/l_h)/dt > 0$ must hold because the land-labor ratio must increase in at least one of the two sectors when t rises. □

Next, we rearrange (15) and substitute it into (13) to derive the wage rate in grain as a function of the horn land-labor ratio:

$$w_{Mg} \;=\; \alpha_g A_g\left(\frac{A_g}{p_h A_h}\,\frac{1-\alpha_g}{1-\alpha_h}\right)^{\frac{1-\alpha_g}{\alpha_g}}\left(\frac{t_h}{l_h}\right)^{\frac{\alpha_h}{\alpha_g}(1-\alpha_g)} . \tag{16}$$

We have now obtained all wage rates as functions of the land-labor ratio in horn, t_h/l_h. Finally, we derive the female wage premium in horn production. We divide (12) by the female marginal product in grain production (using (16) and $w_{Mg} = w_{i,Fg}/\rho_i$) to obtain:

$$\frac{w_h}{w_{i,Fg}} \;=\; \frac{\alpha_h}{\rho_i\,\alpha_g}\left(\frac{p_h A_h}{A_g}\right)^{\frac{1}{\alpha_g}}\left(\frac{1-\alpha_h}{1-\alpha_g}\right)^{\frac{1-\alpha_g}{\alpha_g}}\left(\frac{t_h}{l_h}\right)^{\frac{\alpha_g-\alpha_h}{\alpha_g}} . \tag{17}$$

The return to female labor in horn vs. grain is therefore driven by four components in our model. First, if horn technology is highly productive relative to grain technology (A_h/A_g is large), female wages in horn are comparably high. Second, the same is true if horn products are in high demand, such that p_h is high. Third, $w_h/w_{i,Fg}$ is low if women are relatively productive in grain (ρ_i is high). Finally, $w_h/w_{i,Fg}$ grows when land becomes more abundant, as the following corollary shows.

Corollary 1. *Provided that both sectors operate, the female wage premium in horn is increasing in the aggregate land-labor ratio:* $d(w_h/w_{i,Fg})/dt > 0, \forall i$.

PROOF. Since $\alpha_g > \alpha_h$, $dp_h/dt \geq 0$, and $d(t_h/l_h)/dt > 0$ (Proposition 1), this result follows from deriving (17) with respect to t. □

Because of Corollary 1, abundance in land after the Black Death makes the horn sector more attractive to female labor. In addition, if horn products are superior goods (as historical evidence strongly suggests), higher demand due to increased income ($dp_h/dt > 0$) reinforces this effect.

3.4 Fertility and Female Labor Supply for Given Strength ρ_i

Female labor supply in horn production – and thus fertility – depends crucially on the female wage premium in horn, which in turn rises and falls with the abundance of farmland. In the following, we explain this mechanism for a given female strength ρ_i. The optimization problem (5) yields (for illustration, we substitute b_i and I_i back into the solution):

$$b_i - \underline{b} = \begin{cases} \pi \, \frac{\mu}{1-\mu} \, \frac{I_i - \underline{c} + \epsilon}{w_h - w_{i,Fg}} & \text{if } I_i > \underline{c} \\ \\ \pi \, \frac{\mu}{1-\mu} \, \frac{\epsilon}{w_h - w_{i,Fg}} & \text{if } I_i \leq \underline{c} \end{cases} \tag{18}$$

This solution depends crucially on whether or not there is a female wage premium in horn, $w_h > w_{i,Fg}$. We first consider the case where $w_h \leq w_{i,Fg}$. Then, increasing $l_{i,h}$ unambiguously lowers female welfare because both income and birth rates fall according to (3) and (4), respectively. Thus, female workers do not supply labor in horn production, and we obtain a corner solution with $l_{i,h} = 0$ and $b_i = \pi$. This holds for both $I_i > \underline{c}$ and $I_i \leq \underline{c}$.

Next, we describe the solution when horn labor offers a wage premium, $w_h > w_{i,Fg}$. In the following, we refer to this case as horn production being economically viable for women of strength ρ_i. If the income condition $I_i > \underline{c}$ holds, the first line in (18) describes the solution, and the birth rate b_i increases in wages (income effect). At the same time, b_i falls in the horn wage premium, because a higher $w_h > w_{i,Fg}$ makes celibate work time more rewarding for women (wage premium effect). Which of the two effects dominates depends on how close income is to $\underline{c}$, and is discussed in detail below. Finally, for incomes below $\underline{c}$, the second line in (18) describes the solution, which depends on the ratio of ϵ to $w_h - w_{i,Fg}$. Because ϵ is infinitesimal, any $w_h > w_{i,Fg}$ implies that this ratio is very small. Thus, birth rates are at (or close to) the minimum: $b \simeq \underline{b}$.

Summing up, we distinguish between three regimes for birth rates. When horn does not offer a wage premium ($w_h \leq w_{i,Fg}$), birth rates are constant and high; in the presence of a wage premium ($w_h > w_{i,Fg}$) birth rates are low and constant if income is below $\underline{c}$, and increasing in income if it exceeds $\underline{c}$. Equation (19) gives the corresponding results for female labor supply in horn, $l_{i,h}$. We begin with a low land-labor ratio, such that horn is not economically viable for women of strength ρ_i (i.e., $w_h \leq w_{i,Fg}$); hence, $l_{i,h} = 0$. When land-labor ratios rise and horn labor becomes attractive given strength ρ_i, the solution depends on whether or not female income I_i exceeds $\underline{c}$. If it does not, we are in the second regime of (19), and women of type i work the maximum time in horn, $l_{i,h} = \bar{l}_h$, which just ensures $\underline{b}$ children ($\bar{l}_h \equiv 1 - \underline{b}/\pi$). If income exceeds $\underline{c}$, we obtain the internal solution given by the third regime.[29]

$$l_{i,h} = \begin{cases} 0, & \text{if } w_h \leq w_{i,Fg} \\ \bar{l}_h, & \text{if } w_h > w_{i,Fg} \text{ and } I_i(\bar{l}_h) \leq \underline{c} \\ (1-\mu)\bar{l}_h - \mu \, \frac{w_{i,Fg} - \underline{c} + \epsilon}{w_h - w_{i,Fg}}, & \text{if } w_h > w_{i,Fg} \text{ and } I_i(\bar{l}_h) > \underline{c} \end{cases} \tag{19}$$

There is a complication related to determining the cutoff point between the second and the third regime, i.e., the point where $I_i = \underline{c}$. Income I_i is itself a function of $l_{i,h}$, as given by (3). To resolve this issue, we use the fact that in the second regime $l_{i,h} = \bar{l}_h$, so that the corresponding female income is given by $I_i(\bar{l}_h) = w_{i,Fg}(1 - \bar{l}_h) + w_h \bar{l}_h$. This is the maximum income that can be earned when $w_h > w_{i,Fg}$, under the constraint $b \geq \underline{b}$. We can thus use the income condition $I_i(\bar{l}_h) \leq \underline{c}$ to determine the cutoff point between the second and the third regime.

Note that $I_i(\bar{l}_h)$ is increasing in the *horn* land-labor ratio because all wage rates increase in t_h/l_h (see equations (12) and (16)). In addition, $w_h/w_{i,Fg}$ rises with t_h/l_h, as given by (17). The transition from the first to the third regime can thus be illustrated as a function of the land-labor ratio in horn, as shown in Figure 2.[30] The upper panel depicts both $w_h/w_{i,Fg}$ and $I_i(\bar{l}_h)/\underline{c}$ as functions of t_h/l_h, for women with strength $\rho_i = 0.5$ (the average in our calibration below). The lower panel shows the corresponding female labor supply in horn, $l_{i,h}$, as well as the birth rate b_i. Because of the wage premium condition (dashed line), work in horn is viable for female strength-type i only if it pays more than the marginal product in grain production, $w_{i,Fg} = \rho_i w_{Mg}$. Thus, for $w_h/w_{i,Fg} \leq 1$, women of strength ρ_i do not work in horn, such that $l_{i,h} = 0$ (regime 1 in (19)). Growing t_h/l_h eventually leads to $w_h/w_{i,Fg} > 1$, making the horn sector attractive for female labor (beyond point A). The exact level of $l_{i,h}$ then depends on the income condition, depicted by the solid line in the upper panel. When t_h/l_h – and thus income – is low, i.e., if $I_i(\bar{l}_h)/\underline{c} \leq 1$, women of type i are still below the reference level $\underline{c}$. In this case, they supply the maximum possible female labor in horn, $l_{i,h} = \bar{l}_h$ (regime 2).

[29]Theoretically, there is an additional corner solution that may result in the third regime: If the fraction term is larger than $(1-\mu)\bar{l}_h$ then $l_{i,h} = 0$. However, this case is not relevant for the parameters under which EMP emerges (see Appendix A.1).

[30]At this point, it is convenient to focus on the horn land-labor ratio. All qualitative arguments also hold for the aggregate land-labor ratio T/N (Proposition 1). However, to to derive the exact (increasing) functional relationship between T/N and t_h/l_h, we have to solve for the general equilibrium of the model. Here, it is sufficient to concentrate on the partial equilibrium for a given t_h/l_h in order to illustrate the intuition for female labor supply decisions.

[Insert Figure 2 here]

Further increases in t_h/l_h finally allow consumption above the reference level $\underline{c}$ (point B, where $I_i/\underline{c} = 1$). With t_h/l_h rising beyond this point (regime 3), two effects govern female labor supply decisions. First, the wage premium effect leads to *more* work in horn when w_h increases relative to $w_{i,Fg}$. Second, the income effect implies *less* female labor in horn production (and more children) as income grows.[31] The income effect dominates for all relevant land-labor ratios in our model.[32] Therefore, $l_{i,h}$ falls in t_h/l_h.

This discussion leads to a crucial condition for the emergence of EMP:

Proposition 2. *Women of strength ρ_i make optimal fertility decisions in line with EMP (Definition 1) over some range of aggregate land-labor ratios (T/N) if and only if $\frac{T}{N}\big|_{w_h=w_{i,Fg}} < \frac{T}{N}\big|_{I_i=\underline{c}}$, i.e., if the horn technology offers a wage premium for strength ρ_i at land-labor-ratios that do not yet grant the reference consumption for this strength-type.*

PROOF: See Appendix A.1, where we show that $b_i < \bar{b}$ and that b_i is upward sloping in income over some range if the condition holds, while b_i is always downward sloping otherwise.

While Proposition 2 is formulated for the more general aggregate land-labor ratio, it equivalently applies to the horn-specific land-labor ratio t_h/l_h (Proposition 1). Proposition 2 thus implies that point A in Figure 2 has to be to the left of point B for EMP to emerge. In other words, EMP-fertility behavior emerges for a given strength when income is below $\underline{c}$ at the point where horn becomes economically viable. In this case, the income effect over-compensates the wage premium effect. Thus, on net, $l_{i,h}$ falls in the land-labor ratio – and birth rates rise. On the other hand, if A lies to the right of B, the income effect is relatively weak: When horn becomes viable, women are already relatively rich. At the same time, the horn wage premium is small relative to income. In this setting, women do not forego children for work in horn, so that $l_{i,h} = 0$.[33] Thus, EMP does not emerge. The proof of the proposition builds on this intuition.

Proposition 2 has implications for the relative productivity across sectors that allows EMP to emerge. We assume that the densely populated pre-plague economy has low land-labor ratios such that the horn sector is only attractive for few women. The plague causes massive land abundance. Corollary 2 discusses under which condition this leads to the emergence of fertility behavior in line with EMP.

[31] To understand the income effect, suppose that I_i is close to, but larger than, $\underline{c}$. Thus, $l_{i,h}$ is below its upper bound. Now suppose that productivity *falls* at the same rate in both grain and horn, pulling income yet closer to the reference level but leaving $w_h/w_{i,Fg}$ unchanged. As a result, the marginal utility of consumption rises dramatically. Therefore, for a given premium $w_h > w_{i,Fg}$, female peasants shift labor supply to the horn sector, delaying marriage and giving birth to fewer children over their lifetime. Consequently, the income effect implies that wage rates and female labor shares in horn move in opposite directions.

[32] Technically, the income effect is strong when I_i is relatively close to $\underline{c}$, and eventually becomes minuscule for very large land-labor ratios – in the limit, the model behaves like a standard log-utility setup such as in Galor and Weil (1996). At these high land labor ratios, the wage premium effect is also small relative to the income level. Thus, $l_{i,h}$ and b_i approximately become constant in the limit (see appendix A.1 for further detail).

[33] Technically, the third line in (19) becomes negative if $w_{i,Fg} - \underline{c}$ is large relative to $w_h - w_{i,Fg}$. Thus, the constraint $l_{i,h} \geq 0$ is binding. Intuitively, the wage premium (and thus the cost of children) is so low that – if they could – women would pay to have more than π children.

Corollary 2. *The following properties favor the emergence of EMP fertility behavior after large population losses: (i) TFP in the grain sector, A_g, is relatively low, (ii) TFP in the horn sector, A_h, is relatively high, (iii) on average women are relatively unproductive in grain production (the mean of ρ_i is relatively small), and (iv) horn is a luxury product so that its relative price increases with income.*

PROOF: See Appendix A.2.

We show in section 3.9 that conditions (i)-(iii) were more likely to hold in Europe than in China when both regions were hit by the plague in the 14th century. Historical evidence presented in Section 4.2 also suggests that demand for horn surged after the Black Death, supporting condition (iv).

3.5 Heterogeneous Strength, Aggregate Labor in Horn, and Fertility

So far, we have analyzed fertility and labor supply decisions for individual women of a given strength ρ_i. We now derive the aggregate behavior, averaging across all strength types. The average birth rate is given by $b = \int_0^1 b_i(\rho_i) f(\rho_i) d\rho_i$. We use a beta distribution for $f(\cdot)$, which ensures that female strength ρ is in the unit interval. We set both shape parameters equal to 2 – this is the simplest form of a symmetric distribution with mean 0.5.[34] Figure 3 shows that women of low and high strength react differently to rising land-labor ratios. We use values for ρ_i^{low} and ρ_i^{high} that are one standard deviation below and above the mean of our strength type distribution, respectively. The left panel shows that women with ρ_i^{low} begin to work in horn at relatively low land-labor ratios (point A). This is because their foregone wage in grain production is low, so that even small horn wages are attractive. In addition, income in point A is below the reference level $\underline{c}$. Thus, the horn wage premium provides a large marginal utility, so that women of type ρ_i^{low} work the maximum amount of time in horn, $\bar{l}_h$. This is in stark contrast to women with strength ρ_i^{high} (right panel). For these, income exceeds $\underline{c}$ already at low land-labor ratios due to their high productivity in grain. At the same time, the horn sector is unattractive, not offering them a wage premium.[35] Thus, physically strong women do not work in horn, because for them point A is located to the right of point B (when horn becomes viable, income already exceeds the reference level $\underline{c}$). Note that increasing female strength moves point A to the right and point B to the left – making it less likely that fertility restriction will arise for stronger women. In Appendix A.3 we discuss this in more detail and derive the cutoff strength type $\rho_{A=B}$ for which A and B coincide – i.e., the maximum female strength at which women still make fertility choices in line with EMP.

[Insert Figure 3 here]

Next, we derive the average horn labor supply and fertility across all strength types. Figure 4 shows the average woman's labor in horn, implied by individual behavior together with the strength distribution. Initially, female labor in horn rises in the land-labor ratio. This is because horn becomes attractive for

[34] Appendix A.3 shows the distribution. Higher values for the shape parameters lead to tighter distributions. We show in Appendix A.6 that our results are robust to alternative specifications.

[35] For large land-labor ratios, the horn sector will eventually offer a wage premium. However, this is so small relative to income that it does not incentivize women to work in horn (see footnote 33).

increasingly stronger women. They work at the limit $\bar{l}_h$, because their income is below $\underline{c}$ (see the left panel of Figure 3). Eventually, at sufficiently high land-labor ratios, further increases do not attract additional women into horn production.[36] In addition, women who already work in horn provide less labor than previously because their wages are above the reference level $\underline{c}$ (see the range to the right of point B in Figure 2). In combination, an increase in the land-labor ratio first fosters female labor in horn, but eventually leads to declining labor in horn by raising female incomes beyond $\underline{c}$. Correspondingly, fertility first decreases with land abundance but then increases. Note that throughout this discussion we have focused on the female labor supply in partial equilibrium. In the following, we close the model by adding labor and goods demand. This allows us to determine two central parameters in general equilibrium that we have taken as given so far – the share of land dedicated to horn production (t_h), and the relative price of horn (p_h).

[Insert Figure 4 here]

3.6 Closing the Model: Demand Side and Market Clearing

In this section we introduce the consumption preferences across the two goods, describe demand, and close the model. We use standard Stone-Geary preferences, where consumption of horn products only takes place if at least $\underline{c}$ of grain is consumed. This is in line with our interpretation of $\underline{c}$ as a reference consumption level that satisfies basic needs. For women with $I_i > \underline{c}$, the expenditure shares for the two products are given by:

$$\begin{aligned} \frac{c_{i,g}}{I_i} &= \phi + (1-\phi)\left(\frac{\underline{c}}{I_i}\right) \\ \frac{p_h c_{i,h}}{I_i} &= (1-\phi) - (1-\phi)\left(\frac{\underline{c}}{I_i}\right) \end{aligned} \tag{20}$$

where $c_{i,g}$ ($c_{i,g}$) is grain (horn) consumption of women with strength-type i, and ϕ is the weight on the grain part of utility.[37] When $I_i \leq \underline{c}$, all income is used for grain consumption: $c_{i,g} = I_i$ and $c_{i,h} = 0$. Preferences of male peasants have the same structure, with I_i replaced by w_{Mg}. Appendix A.4 states the preferences in detail and shows that the implied indirect utility is compatible with our general setup in (2). The expenditure shares in (20) imply that once consumption passes the reference level, peasants spend growing proportions of their income on horn products. For very high income levels $I_i >> \underline{c}$, the horn expenditure share converges to the constant $1 - \phi$. Therefore, the horn demand effect driven by the non-homothetic preferences is strongest when income is still relatively low, which coincides with the emergence of EMP.

Aggregate demand for the two products is obtained by integrating over all strength types for the N women, and by using the homogeneous income w_{MG} for the N men. Market clearing implies that total peasant expenditures for each product must equal total output, net of the landlord's consumption. We have

[36] At such high land-labor ratios, horn offers a wage premium even for strong types with $\rho_i > \rho_{A=B}$. However, for these women work in horn is not attractive (their point A lies to right of point B; see the right panel of Figure 3, as well as Appendix A.3).

[37] The ratio of expenditures for the two products can be written as $(c_{i,g} - \underline{c})/(p_h c_{i,h}) = \phi/(1-\phi)$. Thus, the expenditure shares *relative* to $\underline{c}$ are constant, as in a common Cobb-Douglas utility setup.

now fully specified the model; we first solve it for a given land-labor ratio $t = T/N$. This yields aggregate birth rates and death rates as functions of t – and thus also as functions of income per capita. In Appendix A.5 we show the related algebra and explain how we solve the system of equations.

3.7 Model Parameters

Our model's main purpose is to illustrate the mechanism leading to the emergence of EMP. We estimate the quantitative importance of our mechanism in the empirical section below. Thus, the exact parameter values mainly serve an illustrative purpose. Whenever concrete numbers for parameters can be derived from historical figures, we use these. For the remainder, we choose simple approximations. We focus on England, where data is relatively abundant, and where births were particularly responsive to economic conditions (Lee, 1981; Wrigley and Schofield, 1981). For the labor shares of production in grain and horn we use $\alpha_g = 0.7$ and $\alpha_h = 0.4$.[38] For the average productivity of women relative to men in grain we use $\rho = 0.5$, reflecting the fact that English women's wages were equivalent to 50-63% of English male wages (Kussmaul, 1981; Allen, 2009); this is also compatible with the range reported by van Zanden (2011) for relative female wages in reaping and haymaking. For the corresponding beta distribution we use a simple symmetric form with a mean of 0.5 (as discussed in Section 3.5).[39]

Turning to the demographic parameters, we choose $\pi = 3$ (peasant families have three children when women do not work in horn), $\underline{b} = 2$ (two children is the lower bound for birth rates). This captures the fact that EMP avoided up to one third of all births (Clark, 2007).[40] For the elasticity of death rates with respect to income we use $\varphi_d = -0.25$. This is the average across all 50-year estimates for England from Kelly and Ó Grada (2010) between 1600 and 1800.[41] We choose $d_0 = 0.84\pi$ in (6). This implies that there is already some horn production prior to the Black Death. Dyer (1988) shows that livestock products account for about 50% of the value of food consumption during the high-wage decades after 1350. The corresponding share in the model is given by $1-\phi$ for a rich economy. We thus use $\phi = 0.5$ for the parameter in the Stone-Geary utility function. The remaining parameters can be chosen with greater degrees of freedom. We use $\mu = 0.5$ for the relative importance of children in female utility (alternatively, 0.25 or 0.75 yield very similar results). We normalize $\underline{c} = 1$ and land $T = 1$. Finally, we choose TFP in grain and horn, $A_g = 3.5$ and $A_h = 1.50$.

[38] This is calculated as follows: We take the estimates of revenue and cost on arable and pastoral farms from Allen (1988) and combine them with the figures for labor cost per acre from Allen (1991). We find that both relative to costs and revenue, labor's share in pastoral farming is approximately half of the value in arable production. This determines the relative magnitudes of α_g and α_h. To calculate the levels, we use an average labor share in agriculture of 0.5. According to the figures in Broadberry, Campbell, and van Leeuwen (2011), arable production was 32% of total agricultural production, while pastoral farming accounted for 68%. We chose $\alpha_g = 0.7$ and $\alpha_h = 0.4$ so that the average weight of labor in agriculture is identical with the value of 0.5: $0.32 \times 0.7 + 0.68 \times 0.4 = 0.496$.

[39] Our baseline setup with both parameters of the distribution equal to 2 implies a standard deviation of 0.22. The model is robust to alternative parameters. For example, choosing 5 instead of 2 for both parameters (implying a standard deviation of .15) yields very similar results.

[40] Note that this is a conservative choice for an upper bound. Because strong women do not work in horn, aggregate fertility does not drop down to $\underline{b}$. Choosing lower values for $\underline{b}$ implies a steeper decline in fertility.

[41] In Appendix A.6 we discuss the implications of alternative choices for this parameter.

3.8 Steady States and Stability of EMP

We now turn to the steady states and the contribution of EMP to sustaining higher p.c. income levels after the Black Death. Figure 5 shows the simulation results for our complete model. We plot average peasant household income on the vertical axis, which increases in the land-labor ratio. The economy has two stable steady states. The first (E_L) has high population pressure and low p.c. income, while the second (E_H) involves lower fertility and higher peasant income. The unstable steady state E_U lies in between. A large income shock (such as the Black Death) can trigger the emergence of EMP. This occurs when the increase in land-labor ratios is large enough to push the economy beyond E_U, inducing the transition from E_L to E_H. Average peasant income at E_H is about double the pre-plague level. While this is above the increase in wages after the Black Death, we do not expect our simple parameterization to pin down historical magnitudes exactly.[42] What is important is that our findings underline the role 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 two other factors in Voigtländer and Voth (2013) in detail.

[Insert Figure 5 here]

3.9 International Comparisons

Europe was not the only area to suffer from deadly 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 argue that specific European characteristics are responsible for the emergence of EMP, and that other regions were less likely to evolve a similar way of reducing fertility.

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 differences evolve?

In Southern Europe, both age at first marriage and the percentage never marrying were lower than in the Northwest. 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.[43] Rapid recoveries of Southern European populations also reversed post-plague wage gains. Changes in agriculture were less pronounced there. 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 similar social and economic changes? According to Corollary 2, A_h/A_g

[42] We obtain similar results for perfect substitutability between horn and grain, i.e., when shutting down the demand effect so that all results are driven by land abundance (Appendix A.6).

[43] 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).

is crucial. We argue that low horn productivity A_h prevented the emergence of EMP in Southern Europe, while high grain productivity A_g had the same effect in Eastern Europe.

Agricultural conditions in Mediterranean countries did not favor the pastoral farming of the type common in Northwestern 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.[44] Traversing sparsely populated areas on their own was not compatible with women's social role in early modern Europe. Work in husbandry was predominantly performed by men. Without the rise of service in husbandry as a typical phase in young women's life, marriage ages remained low.[45]

In Eastern Europe, grain productivity was high. Especially in Western Russia and Ukraine, land is unusually fertile (Nunn and Qian, 2011). In addition, labor was not free, and wages did not surge to the same extent as in Western Europe after the plague. Instead, landlords continued to farm their estates using serf labor in arable production. Population declines in Eastern Europe were probably smaller than they were in the West (Benedictow, 2004). In the presence of high grain productivity, and without a major jump in land-labor ratios, cattle and sheep farming remained uncompetitive vis-a-vis grain production.

Comparison with China

China also suffered from a devastating plague outbreak in the 14th century, but it did not develop fertility restriction comparable to EMP. We first summarize Chinese demographic patterns and then apply the main insights from our model to this case. Why did the same shock not lead to the emergence of a 'low pressure' demographic regime? We argue that high Chinese grain productivity A_g was key.

In contrast to Europe, marriage in China occurred early and was near-universal for women. For the period 1640-1870, the percentage of women not married by age 30 ranged from 4% in Beijing to 1% in Liaoning (Lee and Feng, 1999). The age at first marriage for women was also low. Amongst members of the Imperial Qing family in Beijing, age at first marriage was 15.5-19 years in the 17th century. By 1840, it had risen to 22 years. Marriage outside the urban areas, and amongst those not belonging to the nobility, probably continued to occur much earlier. In the early 20th century, Chinese women on average married aged 17.5 (Lee, Feng, and Ruan, 2001).[46]

In Appendix B.3 we show that grain production in China was approximately 4 times more efficient than

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

[45]Similar questions could be raised about the non-emergence of EMP in the early medieval period, when land-labor ratios were high. For the emergence of EMP, a large-scale, commercial-operated horn sector is key. While we do not explicitly model this aspect, functioning markets for relatively long-distance trade were crucial. These did not exist in the early Middle Ages.

[46]While irrelevant for fertility, the same was not true in the case of men. A significant proportion remained unmarried by age 30. The main reason was the unavailability of women. Due to female infanticide, and the practice of taking multiple wives, many men could not marry. The overall proportion in 1800 was around 22%, compared to 45% in England, Norway, and Sweden. The average age at marriage for men was 21-22 (Lee and Feng, 1999). Appendix B.3 provides further discussion.

in England. Following Corollary 2, higher grain productivity makes the emergence of EMP less likely, by lowering the wage premium that horn labor can offer to women. Thus, our model suggests that – paradoxically – China's high land productivity, as emphasized by the revisionist 'California School' (Pomeranz, 2000; Goldstone, 2003), undermined the evolution of fertility limitation. Also, as population pressure mounted in China, ploughing with oxen disappeared. Consequently, the strength requirements for grain and rice production were lower. This eroded the relative male advantage in the grain (rice) sector. Therefore, the relative female productivity in grain, ρ, was higher than in Europe. As Corollary 2 shows, this made the emergence of EMP more difficult. In sum, large A_g paired with relatively high ρ in China avoided the shift to pastoral agriculture and thus the emergence of a female labor market outside the household.

4 Empirical Evidence

According to our model, pastoral production leads to more employment opportunities for women as servants. This causes the female age at first marriage to rise. In this section, we test this prediction. We first show that pastoral production was indeed correlated with a high share of unmarried females, and that this was already true in the Middle Ages. To demonstrate this, we use several types of new data. From 14th century tax records, we construct proxies for the share of unmarried females, county-by-county, in 1381 – shortly after the plague. In addition, we use detailed data from employment records of early modern English farms to show that pastoral farms used female labor on a far greater scale.

The second prediction of our model concerns the expansion of pastoral production after 1349. We show that there was a massive rise in pastoral output as incomes surged. We then examine our third empirical prediction – that late female marriage was "sticky." Once EMP had reached its full strength, it did not disappear for centuries. We analyze data on the female age at first marriage in panel of parishes, compiled by the Cambridge Group of Population Studies (CAMPOP). High suitability for pastoral agriculture (due to soil and climate characteristics) predicts markedly later ages at first marriage for women. In addition, in these areas, servants mostly worked in livestock farming, as indicated by the seasonality of marriages. Finally, where a drastic shift away from arable farming towards pastoral farming occurred after the Black Death, female ages at marriage were markedly higher even centuries later. Table 2 summarizes the evidence we employ and the steps of the causal chain they refer to. In the following, we begin with evidence from the middle ages, move on to the early modern period, and then use data from the mid-19th century.

[Insert Table 2 here]

4.1 Pastoral production and unmarried females in the Middle Ages

Since there is no direct way to estimate the age at first marriage in England before the 16th century, we rely on a proxy variable for marriage behavior – the implied share of unmarried women as reflected in the poll tax returns of 1377 and 1381.[47] The tax charge levied on each person increased three-fold over the four years.

[47] If women eventually get married, the proportion of unmarried females is a good proxy for the age at first marriage.

This lead to wide-spread evasion in 1381, with the number of tax payers dropping by more than one third: "[E]very shire of England returned an incredibly small number of adult inhabitants liable to the impost. The adult population of the realm had ostensibly fallen from 1,355,201 to 896,481 persons. These figures were monstrous and incredible (Oman, 1906)." What is of interest to us is *which* taxpayers disappeared from the records between 1377 and 1381: "A glance at the details of the township-returns...reveals the simple form of evasion...most villages show an enormous and impossible predominance of males in their population, and an equally *incredible want of unmarried females*."[48] In Appendix B.6 we provide confirming evidence from a sample of 193 settlements in 22 counties for which individual poll tax records survived. We show that 'missing unmarried women' can account for a substantial proportion of the drop in tax payers.

There is data on the aggregate number of taxpayers in 1377 and 1381 for 38 counties. The drop in their number has a mean of .33 and ranges from .07 to .65. We use data on land usage in 1290 ($Pastoral^{1290}$) from Broadberry et al. (2011) to determine which counties were predominantly pastoral.[49] Figure 6 shows a strong and positive correlation of the drop in taxpayers with the share of pastoral land in 1290. In Table 3, we test the link statistically. Column 1 shows that the correlation is positive and highly significant. In column 2, we control for population density, and column 3 includes regional fixed effects. The size and significance of the coefficient on pastoral land use is largely unaffected. The magnitude of the coefficient indicates that a one-standard deviation (.15) increase in the share of pastoral land in 1290 is associated with a 10-15% drop in the number of tax payers.[50]

[Insert Figure 6 here]

One obvious concern is omitted variable bias, with a variety of factors influencing marriage ages or celibacy that could be correlated with pastoral land use.[51] To sidestep causality issues, we exploit the suitability of land and climatic conditions for grazing as an instrument, using the number of days during which grass can grow in different English counties from Down, Jollans, Lazenby, and Wilkins (1981).[52] The exclusion restriction is that female marriage age is only influenced by grass suitability via the effect on the *share*

[48]Oman (1906, p.23); our emphasis. For full quotation, see Appendix B.9. A similar point is made by Goldberg (1990, p.195): "Married couples are seemingly over-numerous; solitaries, females especially, but also servants, too few. The population recorded compares unfavourably...with totals recorded for earlier taxes." Without massive evasion, the overall turnout of the poll taxes in 1377 and 1381 should have been similar – in the former, every person of fourteen years and older was liable, in the latter, everybody fifteen and over.

[49]Broadberry et al. (2011) give information on the share of land used for arable farming. We use (1-arable) as our measure of pastoral farming. In Appendix B.5 we show that this proxy is very close to the actual share of pastoral land (using data from 1836), and that it is strongly associated with livestock production.

[50]In Appendix B.6, we examine the proportion of unmarried *men* in a sample of settlement-level tax returns – this proxy allows us to shed more light on the magnitude of effects. We show that a one standard deviation increase in $Pastoral^{1290}$ is associated with roughly a 3.7% decline in the proportion of unmarried men.

[51]Such a factor could be higher per capita income driving up the demand for dairy and beef, and simultaneously encouraging later marriage.

[52]Appendix B.5 provides additional detail and shows that the first-stage relationship between the share of pastoral land and $\ln(daysgrass)$ is strong and robust to controlling for general crop suitability. It also shows that our results are very similar when including general crop suitability as an additional instrument, predicting which regions are *relatively* less suitable for pastoral production because of their high arable productivity.

of pastoral land in each county.[53] In column 4 we use $\ln(daysgrass)$ as an instrument for $Pastoral^{1290}$. The instrument is strong, with the first-stage F-statistic well above 10. The estimated coefficient under IV is larger than in the same specification under OLS (column 1). This is what one should expect given that the pastoral share in 1290 is only a proxy and likely measured with error.

[Insert Table 3 here]

4.2 Agricultural Production and Consumption after the Black Death

Prior to the Black Death, population was increasing while land was in fixed supply – output per capita was stagnant (Campbell, 2000; Broadberry et al., 2011). Then, the Black Death killed one third to half of the population. Output per capita surged, and 1350 became a turning point for real wages. By 1450, real wages in England were 50% higher than they had been on the eve of the plague (Clark, 2005). Per capita consumption of food overall increased. As consumers grew richer, their consumption patterns shifted from 'corn to horn' (Campbell, 2000). More money was spent on 'luxury foods:' Meat and milk consumption increased markedly. For farm workers on large estates, we can quantify these changes: The percentage of calories from meat and fish rose from 7% in 1256 to 26% in 1424 (Dyer, 1988). The Great Plague also caused major changes in production (Apostolides, Broadberry, Campbell, Overton, and van Leeuwen, 2008):

> Between the mid-thirteenth century and the mid-fourteenth century, factor costs and property rights encouraged lords to...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. ...Lords...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...

Campbell (2000) estimates that grain acreage declined by approximately 15 percent after 1349, while livestock reared for meat and milk increased by up to 90 percent. Sheep-farming husbandry expanded everywhere. The estimates of Broadberry et al. (2011) suggest that pastoral output increased rapidly between 1348 and 1555, while arable output only grew slowly. The share of pastoral production in agricultural value added went from 47 to 70 percent, while that of arable declined from 53 to 30 percent between 1270-79 and 1450-59.

Large landowners switched to pastoral farming for two reasons: First, it economized on labor. Per acre, husbandry required 15-25% fewer hands than arable production (Allen, 1988). Second, cheap labor (in particular, of women) replaced that of adult males. We use data from Allen's (1988) estimates of labor usage to demonstrate the size of the effects involved. The average reduction in labor cost is substantial – for farms of the same size, the labor cost per acre on average was fully a quarter lower. Since pastoral farms

[53] Note that we instrument for the *proportion* of land used in pastoral production, so that the extent to which our instrument is correlated with overall agricultural fertility does not affect our results.

were on average five times larger, they also profited from economies of scale (Allen, 1988). In combination, this means that average costs per acre in pasture were 75% lower than in arable farming.[54] Allen's (1991) early modern data also demonstrate that switching from arable to pastoral farming was associated with a larger role for women in the labor force. Switching to livestock farming increased the share of females employed from 26 to 34% on smaller farms (100 acres), and from 19 to 31% on larger ones (250 acres; see Appendix B.1 for detail). This is because livestock production is particularly well-suited to women and children (Smith, 1981). Work as shepherdesses, as milkmaids or in spinning required less physical strength than plough agriculture. The switch from 'corn to horn' therefore implied a shift in demand from male to female labor. It also involved hiring more help from outside the family. Allen (1988) shows that the average ratio of hired to family labor was 2.3:1 in pastoral farming, but only 1.5:1 in arable.[55]

4.3 Pastoralism and Marriage Ages after 1600

Next, we examine the association between pastoral output and marriage ages during the early modern period. We first show that the share of land used for livestock farming is a good predictor of the age at first marriage, and that the *shift* out of arable and into pastoral farming after the Black Death is also associated with a higher age at first marriage. In addition, we demonstrate that spring marriage – reflecting the seasonality of pastoral agriculture – is a strong predictor of late female marriage. Finally, the 1851 British census provides direct evidence that farm service was associated with markedly lower marriage rates.

As the main dependent variable, we use detailed data from family reconstitutions compiled by CAMPOP, which reconstructed the complete family "trees" of 26 parishes in England starting in 1541 (Wrigley et al., 1997).[56] The average age of first marriage for women in the sample is 25.0, with a (county-level) minimum of 21.6 and a maximum of 28.6.

How much of the variation in marriage ages can be explained by the prevalence of pastoral farming and the switch from "corn to horn" in the Middle Ages? One direct measure of the switch to pastoral production comes from deserted medieval villages (DMVs) in England (Beresford, 1989). Villages were abandoned in the late medieval period for a variety of reasons, including general population decline after the Black Death. One important consequence was the move to pastoral farming, especially sheep farming – areas where once cereals had been cultivated by local farmers were turned over to grazing.[57]

The shift to pastoral farming was massive, and it was near-permanent. If we simply examine mean first female marriage age, conditional on the density of DMVs per county, we find a clear pattern. Appendix B.7 provides a more detailed analysis and shows the distributional graph. The modal age at marriage was

[54] Appendix B.1 provides more detail on these numbers and plots the cost of labor per acre for a variety of farm sizes, for both pastoral and arable farms. Allen's data is based on Arthur Young's travels in England during the 18th century. He argues that labor-saving in pastoral farming relative to arable was even stronger in 1600 and 1700 (Allen, 1988).

[55] In Appendix B.2, we examine anthropological evidence on the use of female labor. It clearly shows that pastoral agriculture is more compatible with the employment of women.

[56] Their data on age at marriage is given for 26 parishes and five periods between 1600 and 1837. We geo-referenced the parishes analyzed by CAMPOP and matched them to county-level data on agricultural production and suitability.

[57] Broadberry et al. (2011) exploit information on DMVs to quantify the change from "corn to horn" after 1290. A full quote of their assessment is in Appendix B.9.

markedly higher in parts of England with more abandoned medieval villages, reflecting a strong shift towards pastoralism after the Black Death.

In Table 4, we examine the effect of pastoralism and DMVs on the female age at first marriage. In columns 1-3, we present results for the entire period covered by CAMPOP – five periods between 1600 and 1837.[58] We find strong effects throughout. Both $Pastoral^{1290}$ and DMV are significantly correlated with the female age at first marriage in our panel (column 1). Using fixed effects for larger regions to control for unobserved heterogeneity (column 2) does not change our results. In column 3 we re-estimate our results with $\ln(daysgrass)$ as an instrument for $Pastoral^{1290}$. We find large and significant coefficients for both the share of pastoral land use in 1290 as well as for our proxy of medieval land conversion to livestock farming (DMV). The coefficients are similar if we restrict our sample to the period 1600-1749 excluding the period after the onset of the Industrial Revolution (columns 4-6). The effects are quantitatively important. A one standard deviation increase in the share of land devoted to pastoral farming in 1290 (.15) went hand-in-hand with average female first marriages occurring .6-1.2 years later; a one standard deviation increase in the number of DMVs per 100,000 acres raised marriage ages by a third to half a year. How important was pastoral production overall for late marriage? The variable $Pastoral^{1290}$ has a mean of .57. Given our preferred specifications in Table 4 – the IV estimates in columns 3 and 6 – this implies that pastoralism overall raised the average age of female marriage by more than 4 years.

[Insert Table 4 here]

We can also show that the link between pastoral land use and late female marriage is closely associated with the employment of female servants in the pastoral sector. Kussmaul (1990) collected data on the seasonality of marriage from Anglican marriage registers for 542 parishes in England. These are classified as pastoral-type (P) if marriage frequency during the autumn was low, but high in the spring: Servants in husbandry would typically marry after the lambing season in spring. Workers in arable areas, in contrast, often married after the harvest season, in the late summer. We use the county-level share of parishes with spring marriage pattern as the explanatory variable.[59] Table 5 shows a strong positive association between pastoral marriage patterns and the age at first marriage. In column 1, we exploit both time-series and cross-sectional variation. The effect is strong and significant in the sample overall (Panel A), but it is smaller and not statistically significant when we exclude data after 1749 (Panel B). Column 2 includes time period dummies to control for overall trends in pastoral production and age at marriage. While the magnitude of the coefficients is unchanged, the standard errors are now marginally greater than necessary for conventional levels of significance.

[Insert Table 5 here]

[58] All regressions include period fixed effects. The 26 parishes are located in 15 different counties. Because the explanatory variables are observed for each county, we cluster standard errors at the county level.

[59] Kussmaul (1990) provides data for three periods between 1561 and 1820. We match these to the five CAMPOP periods. Appendix B.7 provides a more detailed description, as well as scatterplots for the regressions presented in the main text.

The Kussmaul measure is inherently noisy because many other factors besides work in husbandry affect the date of marriage. To deal with measurement error, we instrument spring marriages by land use and soil suitability. IV-results (columns 3-4) indicate large and significant effects. For example, the estimation results in column 3 – where we instrument with the pastoral share in 1290 – suggest that a one standard deviation increase in the share of parishes with a pastoral marriage pattern (.13) would raise mean female age at first marriage by .8 years. When using the number of days of grass growth as an instrument, the effect is 30% larger. This implies that the part of marriage seasonality driven by pastoral land use is a powerful predictor of late marriage. The part of the variation in pastoral marriages explained by actual land use or land suitability arguably captures the husbandry channel best. This strongly suggests that pastoral agriculture reduced fertility by offering extra employment possibilities to female servants. In Appendix B.8 we exploit the detailed data available in the 1851 British census to provide further evidence for the main mechanism. While agriculture was a declining part of the English economy, areas that employed farm servants still saw markedly later marriage ages.

In sum, the historical data strongly support all the steps in the causal chain in Table 2. Where women had more employment opportunities in pastoral farming, and more females worked as servants, marriage occurred later. The part of pastoral land use driven by climatic conditions is particularly strongly associated with higher marriage ages; where medieval farms switched from "corn to horn", as reflected by the share of deserted medieval villages, early modern English women took their vows markedly later.

5 Conclusion

Why did Europe evolve a system of delayed marriage that reduced fertility centuries before the demographic transition? We argue that the Black Death was one crucial contributing factor. Fertility restriction emerged as an indirect consequence of the abundance of land after 1348-50, and the associated switch from arable to pastoral farming. The Black Death reduced population by between one third and half. Land-labor ratios rose markedly. This favored pastoral production because it uses land more intensively (Campbell, 2000). Cattle were kept for meat and milk, and sheep for mutton and wool. The rise of large-scale livestock farming translated into a greater economic role for women. Female labor is better suited to shepherding and milking than to ploughing or threshing (Alesina et al., 2011) – a fact borne out by the sexual division of labor in isolated tribes studied by anthropologists (Appendix B.2). After the plague, owners of large estates switched from arable farming, with its high demand for adult male labor, to husbandry, which required less strenuous labor, some of which could be supplied by women. In this way, the Black Death raised the demand for female labor.

Working as a servant involved moving from the parental household to the master's. Contracts forbade marriage. Because the Black Death changed the pattern of production and raised the demand for female labor, it increased the average age at first marriage for women, reducing fertility rates. This in turn lowered population pressure in a Malthusian setting and helped to keep wages high after the Black Death. We thus explain the simultaneous emergence of large-scale pastoral farming, late marriage, higher incomes, and low fertility.

We test the predictions of our model against data from England between the 14th and 19th century. Using information from the Cambridge Group of Population Studies' family reconstitutions, we show that counties specializing in pastoral production registered markedly later average ages at first marriage. In the late 14th century already, areas with more livestock farming had a higher proportion of unmarried women. Also, where farming switched from "corn to horn" after 1350 – as evidenced by numerous medieval villages becoming deserted after the plague – marriage occurred much later, even centuries after the Black Death. These effects are arguably causal. Using a pastoral suitability index based on rainfall and soil temperature as an instrument, we find large and highly significant effects of livestock farming on marriage ages. Overall, we estimate that the existence of a pastoral sector in the English economy raised marriage ages by more than 4 years – equivalent to roughly half of the increase between the Middle Ages and the early modern period.

European women already married later than the age of biological fertility as early as the late Roman period. However, fertility restriction via this channel only became severe in the early modern period, when ages at first marriage in many areas reached levels only seen again today. In a Malthusian world, this had implications for per capita incomes. When birth (or death) rates change, the 'iron law of wages' need not hold.[60] Lower fertility in Europe as a result of EMP was one important factor for the persistence of unusually high per capita incomes long before the Industrial Revolution. In models in the spirit of Acemoglu and Zilibotti (1997) and Voigtländer and Voth (2006), higher incomes facilitate the transition to self-sustaining growth. By stabilizing incomes at a high level by 1700, EMP may well have laid some of the foundations for Europe's industrialization. EMP also reduced the volatility of income – bad shocks were partly compensated by lower fertility. Paradoxically, one of the weaknesses of the European agricultural system – relatively low land productivity in grain – strengthened fertility restriction after the Black Death, laying one of the foundations for Europe's early rise to riches.

References

Acemoglu, D., S. Johnson, and J. A. Robinson (2005). The Rise of Europe: Atlantic Trade, Institutional Change and Economic Growth. *American Economic Review 95*(3), 546–579.

Acemoglu, D. and F. Zilibotti (1997). Was Prometheus Unbound by Chance? Risk, Diversification, and Growth. *Journal of Political Economy 105*(4), 709–51.

Alesina, A., P. Giuliano, and N. Nunn (2011). On the Origins of Gender Roles: Women and the Plough. NBER WP 17098.

Allen, R. C. (1988). The Growth of Labor Productivity in Early Modern English Agriculture. *Explorations in Economic History 25*, 117–146.

Allen, R. C. (1991). The Two English Agricultural Revolutions, 1450-1850. In B. Campbell and M. Overton (Eds.), *Land, Labour, and Livestock: Historical Studies in European Agricultural Productivity*, pp. 236–254. Manchester: MUP.

Allen, R. C. (1992). *Enclosure and the Yeoman*. Oxford: Oxford University Press.

[60] 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.'

Allen, R. C. (2009). Agricultural Productivity and Rural Incomes in England and the Yangtze Delta, c. 1620–c.1820. *Economic History Review 62*(3), 525–550.

Anderson, M. and R. Lee (2002). Malthus in State Space: Macro Economic-demographic Relations in English History, 1540 to 1870. *Journal of Population Economics 15*, 195–220.

Apostolides, A., S. Broadberry, B. Campbell, M. Overton, and B. van Leeuwen (2008). English Agricultural Output and Labor Productivity, 1250-1850: Some Preliminary Estimates. Available at http://www.basvanleeuwen.net/bestanden/agriclongrun1250to1850.pdf.

Ashraf, Q. and O. Galor (2010). Dynamics and Stagnation in the Malthusian Epoch. Department of Economics, Williams College working paper.

Ashraf, Q. and O. Galor (2011). Dynamics and Stagnation in the Malthusian Epoch. *American Economic Review 101*(5), 2003–41.

Barro, R. J. and G. S. Becker (1989). Fertility Choice in a Model of Economic Growth. *Econometrica 57*(2), 481–501.

Becker, G. S. (1960). An Economic Analysis of Fertility. In *Demographic and Economic Change in Developed Countries*, Number 11, pp. 209–231. National Bureau of Economic Research Series, Princeton, NJ: Princeton University Press.

Becker, G. S. (1981). *A Treatise on the Family*. Harvard University Press, Cambridge, MA.

Becker, G. S. and H. G. Lewis (1973). On the Interaction between the Quantity and Quality of Children. *Journal of Political Economy 81*(2), 279–288.

Benedictow, O. J. (2004). *The Black Death 1346–1353. The Complete History*. Woodbridge: The Boydel Press.

Beresford, M. (1989). A Review of Historical Research (to 1968). In M. Beresford and J. G. Hurst (Eds.), *Deserted Medieval Villages*, pp. 3–75. Gloucester: Alan Sutton.

Berkeley, C. G. (1963). *Agricultural Involution: The Process of Ecological Change in Indonesia*. Berkeley, CA: University of California Press.

Boldrin, M. and L. E. Jones (2002). Mortality, Fertility, and Saving in a Malthusian Economy. *Review of Economic Dynamics 5*(4), 775–814.

Brenner, R. and C. Isett (2002). England's Divergence from China's Yangtze Delta: Property Rights, Microeconomics, and Patterns of Development. *Journal of Asian Studies 61*(2), 609–662.

Broadberry, S., B. M. S. Campbell, and B. van Leeuwen (2011). Arable Acreage in England, 1270-1871. Working Paper.

Brown, J. C. and T. Guinnane (2001). The Fertility Transition in Bavaria. Economic Growth Center, Yale, working paper 821.

Butz, W. P. and M. Ward (1979). The Emergence of Countercyclical U.S. Fertility. *American Economic Review 69*(3), 318–328.

Campbell, B. M. S. (2000). *English Seigniorial Agriculture, 1250-1450*. New York: Cambridge University Press.

Chenery, H., M. Syrquin, and H. Elkington (1975). *Patterns of Development, 1950-70*. Oxford University Press.

Chesnais, J.-C. (1992). *The Demographic Transition: Stages, Patterns and Economic Implications*. Clarendon Press, Oxford.

Clark, G. (2005). The Condition of the Working Class in England, 1209-2003. *Journal of Political Economy 113*(6), 1307–1340.

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

Coale, A. J. and S. C. Watkins (Eds.) (1986). *The Decline of Fertility in Europe*. Princeton, N.J.: Princeton University Press.

Crafts, N. F. R. and T. Mills (2008). From Malthus to Solow: How the Malthusian Economy Really Evolved. *Journal* *of Macroeconomics (forthcoming)*.

de Moor, T. and J. L. van Zanden (2010). Girlpower. The European Marriage Pattern and Labor Markets in the North Sea Region in the Late Medieval and Early Modern Period. *Economic History Review 63*(1), 1–33.

Devolder, D. (1999). *Hajnal's European Marriage Pattern and the Evolution of Agrarian Structures*. Forth Worth, Texas: Social Science History Association.

Doepke, M. (2004). Accounting for Fertility Decline During the Transition to Growth. *Journal of Economic Growth 9*(3), 347–383.

Doepke, M., M. Hazan, and Y. Maoz (2012). The Baby Boom and World War II: A Macroeconomic Analysis. Working Paper.

Doepke, M. and F. Zilibotti (2008). Occupational Choice and the Spirit of Capitalism. *Quarterly Journal of Economics 123*(2), 747–793.

Down, K., J. Jollans, A. Lazenby, and R. Wilkins (1981). The Distribution of Grassland and Grassland Usage in the UK. In J. Jollans (Ed.), *Grassland in the British Economy*, Number 10, pp. 580–583. Reading: University of Reading: Centre for Agricultural Strategy.

Dyer, C. (1988). Changes in Diet in the Late Middle Ages: The Case of Harvest Workers. *Agricultural History Review 36*(1), 21–37.

Epstein, L. (2000). *Freedom and Growth: The Rise of States and Markets in Europe, 1300-1750*. London: Routledge.

Eyre, G. E. and W. Spottiswoode (1854). Population Tables II. Ages, Civil Condition, Occupations, and Birth-Place of the People. Vol. I. In *Census of Great Britain, 1851*. House of Commons Parliamentary Papers.

FAO/IIASA (2010). Global Agro-ecological Zones (GAEZ) version 3.0. Technical report, IIASA, Laxenburg, Austria and FAO, Rome, Italy.

Feng, W., J. Lee, and C. Campbell (1995). Marital Fertility Control Among the Qing Nobility: Implications for Two Types of Preventive Check. *Population Studies 49*(3), 383–400.

Fenwick, C. (Ed.) (1998). *The Poll Taxes of 1377, 1379, and 1381: Bedfordshire-Leicestershire*. Oxford University Press for British Academy Records of Social and Economic History.

Fenwick, C. (Ed.) (2001). *The Poll Taxes of 1377, 1379 and 1381: Lincolnshire-Westmorland*. Oxford University Press for British Academy Records of Social and Economic History.

Fenwick, C. (Ed.) (2005). *The Poll Taxes of 1377, 1379 and 1381: Wiltshire - Yorkshire*. Oxford University Press for British Academy Records of Social and Economic History.

Fernandez-Villaverde, J. (2001). Was Malthus Right? Economic Growth and Population Dynamics. PIER Working Paper No. 01-046.

Flinn, M. W. (1981). *The European Demographic System, 1500-1820*. Baltimore: Johns Hopkins University Press.

Foreman-Peck, J. (2009). The Western European Marriage Pattern and Economic Development. Cardiff Economics Working Papers.

Galloway, P. R. (1988). Basic Patterns in Annual Variations in Fertility, Nuptiality, Mortality, and Prices in Pre-industrial Europe. *Population Studies 42*(2), 275–302.

Galor, O. (2005). From Stagnation to Growth: Unified Growth Theory. In P. Aghion and S. Durlauf (Eds.), *Handbook of Economic Growth*, Volume 1, Chapter 4, pp. 171–293. Elsevier.

Galor, O. and O. Moav (2002). Natural Selection and the Origin of Economic Growth. *Quarterly Journal of Economics 117*(4), 1133–1191.

Galor, O. and D. N. Weil (1996). The Gender Gap, Fertility, and Growth. *American Economic Review 86*(3), 374–387.

Galor, O. and D. N. Weil (1999). From Malthusian Stagnation to Modern Growth. *American Economic Review 89*(2), 150–154.

Galor, O. and D. N. Weil (2000). Population, Technology and Growth: From the Malthusian Regime to the Demographic Transition and Beyond. *American Economic Review 90*(4), 806–828.

Goldberg, P. J. P. (1990). Urban Identity and the Poll Taxes of 1377, 1379, and 1381. *Economic History Review 43*(2), 194–216.

Goldstone, J. (2003). Feeding the People, Starving the State: China's Agricultural Revolution of the 17th and 18th Centuries. *Global Economic History Network Conference. London*.

Greenwood, J., A. Seshadri, and G. Vandenbroucke (2005). The Baby Boom and Baby Bust. *American Economic Review 95*(1), 183–207.

Hajnal, J. (1965). European Marriage Pattern in Perspective. In *Population in History*. London: Arnold: D.V. Glass and D.E.C. Eversley.

Hajnal, J. (1982). Two Kinds of Preindustrial Household Formation System. *Population and Development Review 8*(3), 449–94.

Hallam, H. (1985). Age at First Marriage and Age at Death in the Lincolnshire Fenland, 1252-1478. *Population Studies 39*(1), 55–69.

Hansen, G. and E. Prescott (2002). Malthus to Solow. *American Economic Review 92*(4), 1205–1217.

Heckman, J. and J. Walker (1990). The Third Birth in Sweden. *Journal of Population Economics 3*(4), 235–75.

Herlihy, D. (1985). *Medieval Households*. Harvard University Press.

Herlihy, D. (1997). *The Black Death and the Transformation of the West*. Cambridge, MA: Harvard University Press.

Hume, D. (1854). Of the Populousness of Ancient Nations. In *Philosophical Works*. Black and Tait: London. Essay XI.

Ingram, M. (1985). The Reform of Popular Culture? Sex and Marriage in Early Modern England. In B. Reay (Ed.), *Popular Culture in the Seventeenth Century*. Beckenham.

Jones, C. I. (2001). Was an Industrial Revolution Inevitable? Economic Growth Over the Very Long Run. *Advances in Macroeconomics 1*(2), 1–45. Article 1.

Kain, R. J. (1986). *An Atlas and Index of the Tithe Files of Mid-Nineteenth-Century England and Wales*. Cambridge University Press.

Kelly, M. and C. Ó Grada (2008). The Poor Law versus the Positive Check: Living Standards and Mortality in England since the Middle Ages. *UC Dublin working paper*.

Kelly, M. and C. Ó Grada (2010). Living Standards and Mortality since the Middle Ages. Working Papers 2010/26, School Of Economics, University College Dublin.

Kremer, M. (1993). Population Growth and Technological Change: One Million B.C. to 1990. *Quarterly Journal of Economics 108*(3), 681–716.

Kussmaul, A. (1981). *Servants in Husbandry in Early Modern England*. Cambridge, CUP.

Kussmaul, A. (1990). *A General View of the Rural Economy of England, 1538-1840*. Cambridge: Cambridge University Press.

Laslett, P. and R. Wall (1972). *Household and Family in Past Time*. Cambridge, UK: Cambridge University Press.

Lee, J. and W. Feng (1999). Malthusian Models and Chinese Realities: The Chinese Demographic System 1700–2000. *Population and Development Review 25*(1), 33–65.

Lee, J., W. Feng, and D. Ruan (2001). Nuptiality Among the Qing Nobility: 1640-1900. In T. L. et al. (Ed.), *Asian Population History*. Oxford: Clarendon University Press.

Lee, R. (1981). Short-term Variation: Vital Rates, Prices, and Weather. In E. A. Wrigley and R. S. Schofield (Eds.), *The Population History of England 1541-1871*, pp. 356–401. Cambridge: Cambridge University Press.

Li, B. (1998). *Agricultural Development in Jiangnan, 1620-1850*. New York: St. Martin's Press.

Lucas, R. E. (2002). The Industrial Revolution: Past and Future. In *Lectures on Economic Growth*. Cambridge: Harvard University Press.

Macfarlane, A. (1970). *The Family Life of Ralph Josselin, a Seventeenth-Century Clergyman: An Essay in Historical Demography*. Cambridge: Cambridge University Press.

Maddison, A. (1995). *Monitoring the World Economy, 1820-1992*. OECD Development Centre, Paris.

Maddison, A. (2001). *The World Economy. A Millennial Perspective*. Paris: OECD.

Malthus, T. R. (1798). *An Essay on the Principle of Population*. London: Printed for J. Johnson, in St. Pauls's Church-Yard.

Mincer, J. (1963). Market Prices, Opportunity Cost and Income Effects. In C. Christ (Ed.), *Measurement in Economics*. Stanford: Stanford University Press.

Mingay, G. E. and J. Thirsk (Eds.) (2011). *The Agrarian History of England and Wales, 1750-1850*, Volume VI. Cambridge University Press.

Minge-Klevana, W. (1980). Does Labor Time Decrease With Industrialization? A Survey of Time-Allocation Studies. *Current Anthropology 21*(3), 279–298.

Mitterauer, M. (2003). *Warum Europa? Mittelalterliche Grundlagen eines Sonderwegs*. C.H. Beck: Munich.

Mokyr, J. (1990). *The Lever of Riches*. Oxford: Oxford University Press.

Mokyr, J. and H.-J. Voth (2009). Understanding Growth in Early Modern Europe. In S. Broadberry and K. O'Rourke (Eds.), *Cambridge Economic History of Europe*, Volume 1. Cambridge University Press.

Murdock, G. P. and C. Provost (1973). Factors in the Division of Labor by Sex: A Cross-Cultural Analysis. *Ethnology 12*(2), 203–225.

Neher, P. A. (1971). Peasants, Procreation, and Pensions. *American Economic Review 61*(3), 380–389.

Nunn, N. and N. Qian (2011). The Potato's Contribution to Population and Urbanization: Evidence from an Historical Experiment. *Quarterly Journal of Economics 126*(2), 593–650.

Oman, C. (1906). *The Great Revolt of 1381*. Oxford : Clarendon Press.

Pamuk, S. (2007). The Black Death and the Origins of the 'Great Divergence' across Europe, 1300-1600. *European Review of Economic History 11*(3), 289–317.

Pomeranz, K. (2000). *The Great Divergence: China, Europe, and the Making of the modern World Economy*. Princeton, N.J.: Princeton University Press.

Schellekens, J. (1997). Nuptiality during the First Industrial Revolution in England: Explanations. *Journal of Interdisciplinary History 27*(4), 637–654.

Schellekens, J. (2001). Economic Change and Infant Mortality in England, 1580–1837. *Journal of Interdisciplinary History 32*(1), 1–13.

Schultz, T. P. (1985). World Prices, Women's Wages, and the Fertility Transition: Sweden: 1860-1910. *Journal of Political Economy 93*(6), 1126–1154.

Smith, R. M. (1981). Fertility, Economy, and Household Formation in England over Three Centuries. *Population and Development Review 7*(4), 595–622.

Smith, R. M. (2011). Demography and the Great Divergence: Reconsidering the European and Asian Evidence. Keynote address at the Economic History Society Conference, Cambridge, UK 2011.

Snell, K. (1981). Agricultural Seasonal Unemployment, The Standard of Living, and Women's Work in the South and East, 1690–1860. *Economic History Review 34*(3), 407–437.

UK-ONS (2011). United Kingdom – Office for National Statistics. http://www.statistics.gov.uk.

van Zanden, J. L. (2002). The 'Revolt of the Early Modernists' and the 'First Modern Economy:' An Assessment. *Economic History Review 55*(4), 619–41.

van Zanden, J. L. (2011). The Malthusian Intermezzo. CGEH working paper no. 14.

Voigtländer, N. and H.-J. Voth (2006). Why England? Demographic Factors, Structural Change and Physical Capital Accumulation during the Industrial Revolution. *Journal of Economic Growth 11*, 319–361.

Voigtländer, N. and H.-J. Voth (2013). The Three Horsemen of Riches: Plague, War, and Urbanization in Early Modern Europe. *Review of Economic Studies*. Forthcoming.

Vollrath, D. (2011). The Agricultural Basis of Comparative Development. *Journal of Economic Growth 16*(4), 343–370.

Wrigley, E. and R. S. Schofield (1981). *The Population History of England 1541–1871*. Cambridge: Cambridge University Press.

Wrigley, E. A. (1988). *Continuity, Chance and Change: The Character of the Industrial Revolution in England*. Cambridge: CUP.

Wrigley, E. A., R. S. Davies, J. E. Oeppen, and R. S. Schofield (1997). *English Population History from Family Reconstitution 1580-1837*. New York: Cambridge University Press.

Tables

Table 1: Age of Marriage and Marital Fertility in 17C 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 aged 20 to 44.

Table 2: Steps of Mechanism and Empirical Variables

Pastoral Production ⟹	Farm Service ⟹	Late/no Marriage
• % of land used for pasture in 1290, 1837. • Deserted medieval villages. • Soil and climate suitability: days of grass growth (IV).	• Seasonality of marriage pattern 1561-1820. • Employment share of servants in 1851 census.	• % drop in # of taxpayers 1377/1381. • CAMPOP data on female age at first marriage. • % of unmarried women in 1851 census

Description: The table summarizes the steps of our causal argument and the evidence we employ. We argue that (i) pastoral production was typically associated with (ii) farm service (husbandry), which forced female servants to (iii) postpone marriage or remain celibate.

Table 3: Pastoral Production and a Proxy for the Proportion of Unmarried Women, 1381

Dependent Variable: Drop in Tax Payers, 1377-1381

	(1) OLS	(2) OLS	(3) OLS	(4) IV
$Pastoral^{1290}$	.682***	1.067***	.804***	.952***
	(.116)	(.304)	(.275)	(.180)
$\ln(popdensity)$		.133	.125	
		(.107)	(.115)	
Region FE	no	no	yes	no
R^2	.483	.515	.649	
Observations	38	38	38	38
Instrument				$\ln(daysgrass)$
First Stage F-Statistic#				43.4

Description: We use the drop in the number of tax payers between 1377 and 1381 as a proxy for the proportion of unmarried women at the county level. The regressions thus indicate that more pastoral counties had more unmarried women.

Notes: Robust standard errors in parentheses. Key: *** significant at 1%; ** 5%; * 10%. $Pastoral^{1290}$ is calculated as 1 minus the proportion of land used for arable production in 1290, and $popdensity$ is the population per square mile at the county level in 1290; both variables are from Broadberry et al. (2011).

Kleibergen-Paap rK Wald F statistic. The corresponding Stock-Yogo value for 10% maximal IV bias is 16.4.

Table 4: Pastoral Production and Age at First Marriage (Parish-Level Panel)

Dependent Variable: Female Age at First Marriage

	(1) OLS	(2) OLS	(3) IV	(4) OLS	(5) OLS	(6) IV
Period	1600-1837			1600-1749		
$Pastoral^{1290}$	4.036*	5.973**	8.085***	4.321*	6.817**	7.759***
	(2.166)	(2.554)	(1.895)	(2.235)	(3.089)	(1.838)
DMV	5.905*	7.457**	9.266***	6.623*	6.734	9.076***
	(3.162)	(2.879)	(2.938)	(3.614)	(4.470)	(2.916)
Period FE	yes	yes	yes	yes	yes	yes
Region FE	no	yes	no	no	yes	no
R^2	.448	.669	-	.197	.492	-
Observations	112	112	112	66	66	66
Instrument			$\ln(daysgrass)$			$\ln(daysgrass)$
First Stage F-Statistic#			30.1			36.6

Description: DMV proxies for the shift towards pastoral production after the Black Death. The regressions thus show that female age at first marriage was higher in counties that were (i) already more pastoral before the Black Death in 1349, and (ii) shifted more towards pastoral production thereafter.

Notes: The panel comprises 26 parishes (located in 15 counties) over 5 periods. All explanatory variables and the instrument are measured at the county level, while the dependent variable is observed at the parish level. Robust standard errors in parentheses (clustered at the county level). Key: *** significant at 1%; ** 5%; * 10%. $Pastoral^{1290}$ is calculated as 1 minus the proportion of land used for arable production in 1290, and $daysgrass$ denotes the days per year during which grass grows at the county level (see Appendix B.5 for detail). DMV denotes the number of deserted medieval villages per 100,000 acres at the county level.

[#] Kleibergen-Paap rK Wald F statistic (cluster-robust). The corresponding Stock-Yogo value for 10% maximal IV bias is 16.4 in both columns 3 and 6.

Table 5: Pastoral Marriage Pattern and Age at First Marriage

Dependent Variable: Female Age at First Marriage

	(1) OLS	(2) OLS	(3) IV	(4) IV
PANEL A: Parish Level Panel, 1600-1837				
$PastoralMarriage$	4.436**	3.288	6.149**	9.488***
	(2.054)	(2.421)	(2.656)	(.991)
Period dummies	no	yes	yes	yes
R^2	.096	.410	-	-
Observations	112	112	112	112
Instrument			$Pastoral^{1290}$	$\ln(daysgrass)$
First Stage F-Statistic#			7.5	53.2
PANEL B: Parish Level Panel for 1600-1749				
$PastoralMarriage$	2.681	2.612	6.611***	9.566***
	(2.353)	(2.445)	(2.121)	(.731)
Period dummies	no	yes	yes	yes
R^2	.058	.060	-	-
Observations	66	66	66	66
Instrument			$Pastoral^{1290}$	$\ln(daysgrass)$
First Stage F-Statistic#			11.0	25.2

Description: The regressions show that the female age at first marriage was higher in parishes where marriages typically occurred in spring (after the lambing season), i.e., in parishes with a pastoral marriage pattern.

Notes: The panel comprises 26 parishes (located in 15 counties) over 5 periods. $PastoralMarriage$ is the share of parishes with pastoral (spring) marriage pattern in a county (classified as "P" by Kussmaul, 1990). $Pastoral^{1290}$ is calculated as 1 minus the proportion of land used for arable production in 1290, and $daysgrass$ denotes the days per year during which grass grows at the county level (see Appendix B.5 for detail). All explanatory variables and instruments are measured at the county level, while the dependent variable is observed at the parish level. Robust standard errors in parentheses (clustered at the county level). Key: *** significant at 1%; ** 5%; * 10%. All regressions are weighted by the number of parishes in each county for which the pastoral marriage pattern is reported in Kussmaul (1990).

Kleibergen-Paap rK Wald F statistic (cluster-robust). The corresponding Stock-Yogo value for 10% maximal IV bias is 16.4 in columns 3-4 for both panels.

Figures

Figure 1: Steady States with and without EMP (Europe vs. China)

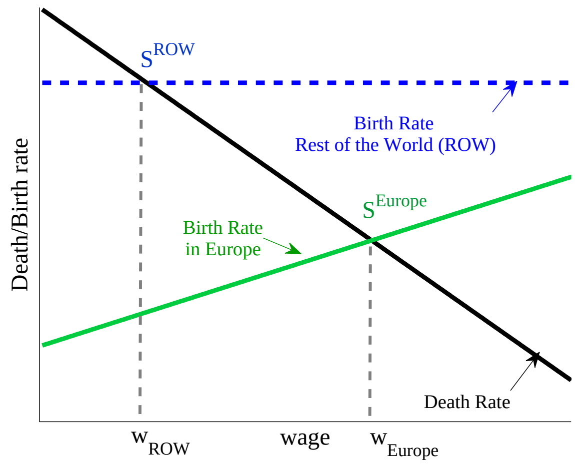
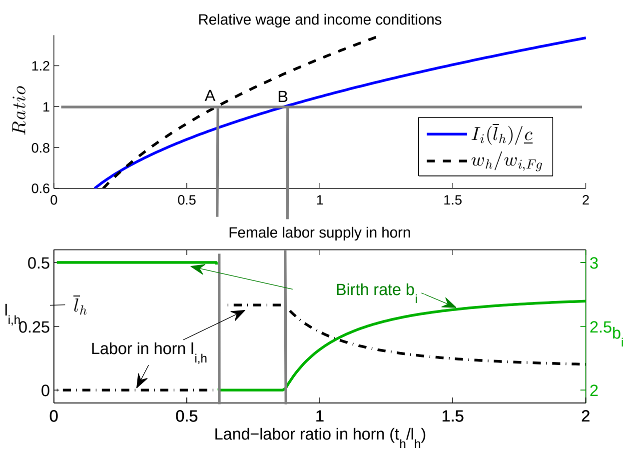
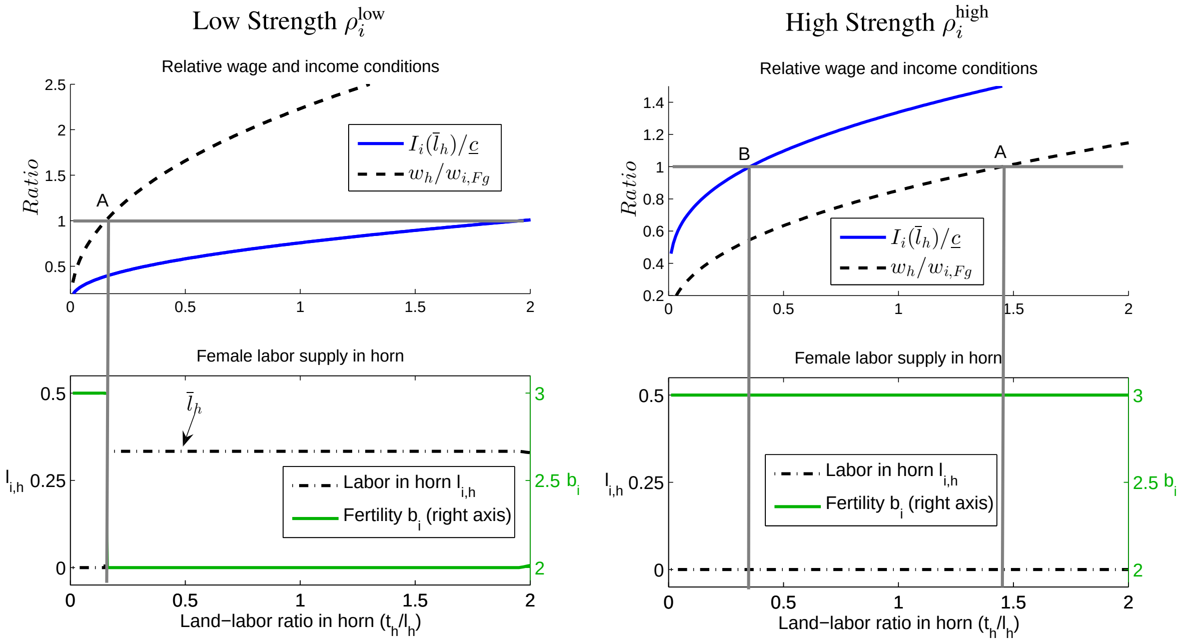


Figure 2: Female labor in horn production for mean strength ρ_i



Note: For land-labor ratios t_h/l_h below point A, the horn technology is not feasible for women of strength ρ_i because it does not offer a wage premium ($w_h/w_{i,Fg} \leq 1$). Thus, female labor in horn is zero. Beyond point A, the horn technology becomes economically viable ($w_h > w_{i,Fg}$). Between A and B, female income for strength-type ρ_i is below subsistence ($I_i \leq \underline{c}$), implying large marginal returns to consumption and thus maximum female labor in horn ($l_{i,h} = \bar{l}_h$). To the right of B, the subsistence effect becomes less important as t_h/l_h increases further, and $l_{i,h}$ falls. The figure uses the mean strength from our calibration, $\rho_i = 0.5$. The lower panel also shows the corresponding birth rate b_i.

Figure 3: Female labor supply in horn for low- and high-strength types



Note: See Figure 2 for a description of points A and B. The left (right) panel uses female strength one standard deviation below (above) the mean in our calibration ($\rho_i^{\text{low}} = 0.276$ and $\rho_i^{\text{high}} = 0.724$, respectively).

Figure 4: Aggregate horn labor supply and fertility

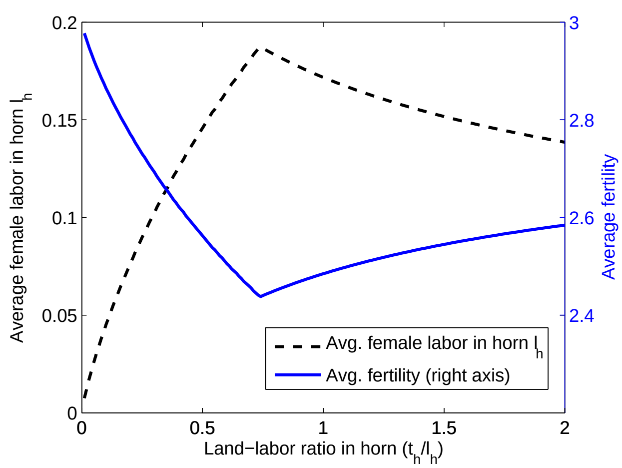


Figure 5: Steady states

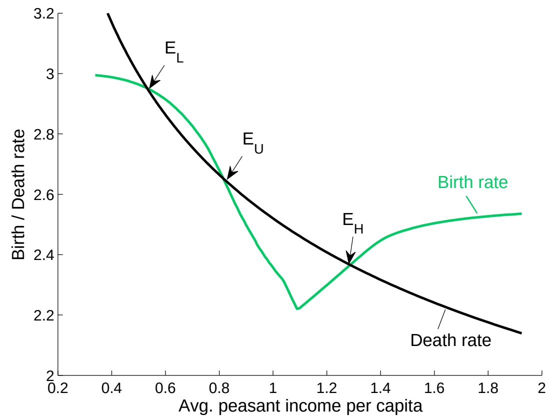
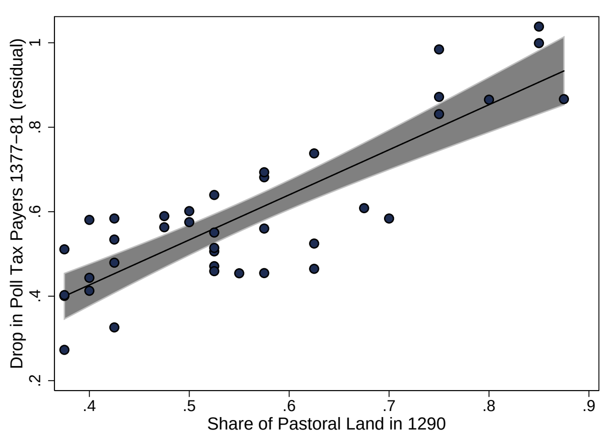


Figure 6: Celibacy and Pastoral Production – Evidence from the 1381 Poll Tax (partial scatterplot)



Notes: The y-axis plots the residual variation in the percentage drop in tax payers between 1377–81, after controlling for county-level population density in 1290. County-level poll tax data for 1377 and 1381 are from Fenwick (1998, 2001, 2005).

Online Appendix

How the West 'Invented' Fertility Restriction

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A Technical Appendix

A.1 Proof of Proposition 2

This section provides the proof for proposition 2 for women of a given strength ρ_i. By definition, EMP requires for strength-type i: (i) $b_i < \bar{b}$ and (ii), b_i to be increasing over some range of $t = T/N$. We show that the first condition holds when horn becomes viable for women of type i ($T/N > \frac{T}{N}\big|_{w_h = w_{i,Fg}}$), irrespective of whether or not income exceeds subsistence at this point. The crucial part of the proof is thus condition (ii), which requires that $l_{i,h}$ in equation (19) be decreasing in female income over some range of $t = T/N$, such that birth rates are increasing. We focus on the third regime in (19), because $l_{i,h}$ and b_i are constant in the other two regimes. As a first step, we re-arrange the third line of (19):[1]

$$l_{i,h} = (1-\mu)\bar{l}_h - \mu \underbrace{\frac{1 - \frac{c}{w_{i,Fg}(t)}}{\frac{w_h(t)}{w_{i,Fg}(t)} - 1}}_{\equiv Z_i(t)} \tag{A.1}$$

Using $b_i = \pi(1 - l_{i,h})$ we obtain:

$$b_i = \underline{b} + \mu(Z_i(t) + \bar{l}_h) \tag{A.2}$$

EMP therefore requires $Z_i(t)$ to be increasing in t over some range.[2] Throughout the proof, we thus focus on the derivative of Z_i with respect to t:

$$\frac{dZ_i}{dt} = \frac{\frac{c}{w_{i,Fg}^2}\left(\frac{w_h}{w_{i,Fg}} - 1\right) \cdot \frac{dw_{i,Fg}}{dt} - \left(1 - \frac{c}{w_{i,Fg}}\right) \cdot \frac{d}{dt}\left(\frac{w_h}{w_{i,Fg}}\right)}{\left(\frac{w_h}{w_{i,Fg}} - 1\right)^2} \tag{A.3}$$

[1] For simplicity, but without loss of generality, we ignore the small positive parameter ϵ. Leaving ϵ in the equation and considering the case $\epsilon \to 0$ yields identical results.

[2] Female income grows hand-in-hand with t over the range where horn is economically viable ($w_h > w_{i,Fg}$).

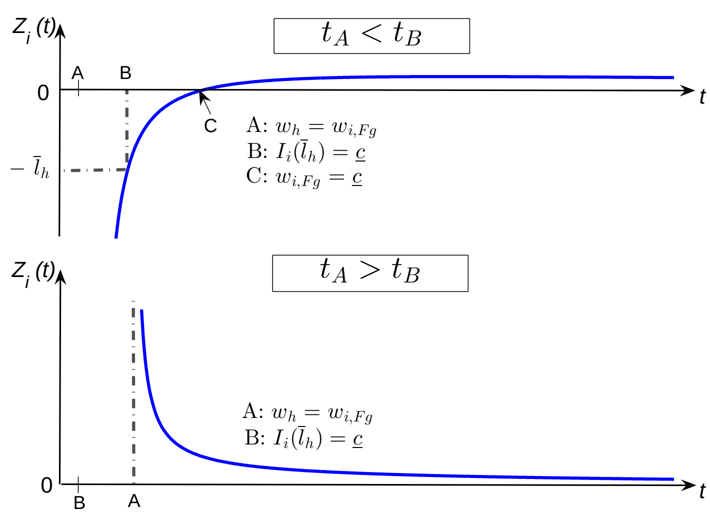
In order to analyze this expression, we obtain $dw_{i,Fg}/dt$ from $w_{i,Fg} = \rho_i w_{Mg}$ and (16), and $d(w_h/w_{i,Fg})/dt$ from (17).

$$\begin{aligned} \frac{dw_{i,Fg}}{dt} &= (1-\alpha_g)\frac{\alpha_h}{\alpha_g}\frac{l_h}{t_h}w_{i,Fg}\cdot\frac{d}{dt}\left(\frac{t_h}{l_h}\right) > 0 \\ \frac{d}{dt}\left(\frac{w_h}{w_{i,Fg}}\right) &= \frac{\alpha_g-\alpha_h}{\alpha_g}\frac{l_h}{t_h}\frac{w_h}{w_{i,Fg}}\cdot\frac{d}{dt}\left(\frac{t_h}{l_h}\right) > 0 \end{aligned} \tag{A.4}$$

Both derivatives are positive because of Proposition 1 and Corollary 1. Throughout the proof, we use the notation $t_{i,A} \equiv \frac{T}{N}\big|_{w_h = w_{i,Fg}}$ (T/N at which horn becomes viable for strength-type i) and $t_{i,B} \equiv \frac{T}{N}\big|_{I_i(\bar{l}_h)=\underline{c}}$ (T/N at which consumption exceeds subsistence). Because the horn technology is not viable for strength-type i below $t_{i,A}$, it is sufficient to focus on $t \geq t_{i,A}$.

We now turn to the first part of the proof – the "if" part of the proposition, showing that $Z_i(t)$ is increasing over some range of t if $t_{i,A} < t_{i,B}$, and that b_i is below its maximum level. Before turning to the formal proof, the upper panel of Figure A.1 illustrates the underlying intuition: We show that $Z_i(t) = -\bar{l}_h$ in point B, is increasing for all t up to (and beyond) point C, and that $Z_i(t)$ eventually becomes decreasing (albeit marginally so) and converges to zero as $t \to \infty$.[3] Following (A.2), this means that $b = \underline{b}$ in B, and then b increases over some range (beyond C) – this increasing part reflects EMP. Eventually, b becomes decreasing in t and converges to $\underline{b} + \mu\bar{l}_h$.

Figure A.1: Functional form of $Z(t)$ in the proof of Proposition 1



We now show this line of argument formally. In point B, we have $I_i(\bar{l}_h) = w_{i,Fg} + \bar{l}_h(w_h - w_{i,Fg}) = \underline{c}$. Re-arranging this expression yields $Z_i(t_{i,B}) = -\bar{l}_h$. For land-labor ratios up to point C, $w_{i,Fg} \leq \underline{c}$.

[3] Note that B lies to the left of C because $I_i(\bar{l}_h) = w_{i,Fg} + \bar{l}_h(w_h - w_{i,Fg}) > w_{i,Fg}$ for all $t > t_{i,A}$.

Therefore, $\left(1 - \frac{\underline{c}}{w_{i,Fg}}\right) \cdot \frac{d}{dt}\left(\frac{w_h}{w_{i,Fg}}\right) \leq 0$ in (A.3). The remaining term in the denominator in (A.3) is positive because $t_{i,B} > t_{i,A}$. Consequently, Z_i is strictly increasing in t for $t \leq t_{i,C}$. In addition, since $Z_i(t)$ and $Z_i'(t)$ are continuous, and since $Z_i'(t_{i,C}) > 0$, there exists a $\delta > 0$ s.t. $\forall \tilde{t} \in (t_{i,C}, t_{i,C} + \delta)$, $Z_i(\tilde{t}) > 0$ and $Z_i'(\tilde{t}) > 0$. That is, $Z_i(t)$ is positive and increasing over some range to the right of C. Next, we show that $Z_i'(t)$ becomes negative, and $Z_i(t)$ converges to zero for large t. Substituting (A.4) into (A.3) and re-arranging yields:

$$\frac{dZ_i}{dt} = \frac{(1-\alpha_h)\underline{c} \; - \; (1-\alpha_g)\frac{\alpha_h}{\alpha_g}\frac{w_{i,Fg}}{w_h}\underline{c} \; - \; \frac{\alpha_g - \alpha_h}{\alpha_g} w_{i,Fg}}{w_{i,Fg}\frac{w_{i,Fg}}{w_h}\left(\frac{w_h}{w_{i,Fg}} - 1\right)^2} \cdot \frac{l_h}{t_h} \cdot \frac{d}{dt}\left(\frac{t_h}{l_h}\right) \tag{A.5}$$

The denominator of this expression is positive, and so is $d(t_h/l_h)/dt$ by Proposition 1. Thus, we can focus on the sign of the numerator in (A.5). The first term in the numerator is constant, the second term converges to zero as t grows large, and the third term increases, following (A.4). Thus, for large enough t the numerator becomes negative such that $Z_i' < 0$.[4] Finally, we show that $\lim_{t\to\infty}(Z_i(t)) = 0$. This follows from (A.1): As $t \to \infty$, the denominator of Z_i becomes large while $\underline{c}/w_{i,Fg}$ goes to zero (both because of (A.4)). Altogether, this delivers the shape of $Z_i(t)$ shown in the upper panel of Figure A.1, which establishes property (ii) of EMP over some range of T/N.

Finally, we show that $b_i < \bar{b}$ over some range that also involves $b_i'(t) > 0$ (that is, there exists a range of t over which both criteria for EMP are fulfilled). The latter holds unambiguously for $t_{i,B} \leq t \leq t_{i,C}$. In addition, in the vicinity of point B, birth rates b_i are close to $\underline{b} < \pi = \bar{b}$, such that $b_i < \bar{b}$. Formally, $\exists\, \epsilon > 0$ s.t. $\forall t_{i,B} \leq \tilde{t} < t_{i,B} + \epsilon : \; b_i < \pi$. This establishes property (i) of EMP and completes the "if" part of the proof.

We now turn to the "only if" part of the proof. It suffices to show that for all $t_{i,A} > t_{i,B}$, $Z_i'(t) < 0, \forall t > t_{i,A}$, such that birth rates b_i are never upward sloping in t, i.e., EMP never emerges. The lower panel of Figure A.1 illustrates the functional form of Z_i for the case $t_{i,A} > t_{i,B}$. We begin by showing that $Z_i'(t)$ becomes large and negative as t converges to $t_{i,A}$ from above. If $t \downarrow t_{i,A}$, $w_h \downarrow w_{i,Fg}$. Since $w_{i,Fg}/w_h \to 1$, (A.5) simplifies and we can derive the limit of $Z_i'(t)$:

$$\lim_{w_h \downarrow w_{i,Fg}} \left(\frac{dZ_i}{dt}\right) = \lim_{w_h \downarrow w_{i,Fg}} \frac{-\frac{\alpha_g - \alpha_h}{\alpha_g}\left(w_{i,Fg} - \underline{c}\right)}{w_{i,Fg} \cdot 1 \cdot \left(\frac{w_h}{w_{i,Fg}} - 1\right)^2} \cdot \frac{l_h}{t_h} \cdot \frac{d}{dt}\left(\frac{t_h}{l_h}\right) = -\infty \tag{A.6}$$

This result follows because (i) the numerator in (A.6) is negative and finite. To see this, note that $\alpha_g > \alpha_h$

[4] Taking the limit of each term divided by the denominator, it is straightforward to show that $Z_i'(t)$ converges to zero from below as $t \to \infty$. For this step, note that $\frac{d}{dt}\left(\frac{t_h}{l_h}\right)$ is positive and finite. To show this we use the fact that for very large t, the expenditure share for horn converges to a constant (see our Stone-Geary setting in Section 3.6), so that p_h is constant in t. Then Proposition 1 implies that rising t leads to increasing land-labor ratios in both sectors. Thus: $\frac{d}{dt}\left(\frac{t_h}{l_h}\right) < \frac{d}{dt}\left(\frac{t}{l_h}\right) = \frac{1}{l_h} - \frac{t}{l_h^2}\frac{dl_h}{dt} < \frac{1}{l_h}$. The last inequality follows because $Z_i' < 0$ for large t, such that (A.1) implies $dl_h/dt > 0$. Finally, $1/l_h$ is finite: As we show below, $\lim_{t\to\infty}(Z_i(t)) = 0$, such that following (A.1), $\lim_{t\to\infty}(l_{i,h}(t)) = (1-\mu)\bar{l}_h > 0$. Since the individual $l_{i,h}$ are finite, so must be the average l_h.

and $w_{i,Fg} > \underline{c}$.[5] Using the latter in (A.1) also implies that $\lim_{w_h \downarrow w_{i,Fg}} Z_i(t) = \infty$, as shown in the lower panel of Figure A.1. (ii) The denominator converges to zero from above, and (iii), l_h/t_h and $d(t_h/l_h)/dt$ are both positive and finite (see footnote 4 for the latter).

Next, we show that $Z_i'(t)$ is negative for all $t > t_{i,A}$ (and thus $w_h > w_{i,Fg}$). Since the denominator in (A.5) is positive and finite ($t > t_{i,A} \Rightarrow w_h > w_{i,Fg}$), it is sufficient to show that the numerator remains negative as t increases beyond $t_{i,A}$. To demonstrate this, we label the numerator in (A.5) $NUM_i(t)$ and show that $NUM_i'(t) < 0,\ \forall t > t_{i,A}$. In other words, the numerator becomes more negative as t increases. Using (A.4) and taking into account that $d(w_{i,Fg}/w_h)/dt = -(w_{i,Fg}/w_h)^2\ d(w_h/w_{i,Fg})/dt$, we obtain:

$$\frac{dNUM_i}{dt} = -\frac{\alpha_g - \alpha_h}{\alpha_g}(1-\alpha_g)\frac{\alpha_h}{\alpha_g}\left(w_{i,Fg} - \frac{w_{i,Fg}}{w_h}\underline{c}\right) \cdot \frac{l_h}{t_h} \cdot \frac{d}{dt}\left(\frac{t_h}{l_h}\right) < 0 \tag{A.7}$$

The inequality holds because $d(t_h/l_h)/dt > 0$ and $w_{i,Fg} > \underline{c} > (w_{i,Fg}/w_h)\underline{c}$ for all $t > t_{i,A}$.[6] Finally, we have already shown that $\lim_{t\to\infty}(Z_i(t)) = 0$ (this holds irrespective of $t_{i,A} \lesseqgtr t_{i,B}$). Altogether, the second part of the proof shows that Z_i' is negative and large for $t \downarrow t_{i,A}$, remains negative for all $t > t_{i,A}$, and converges to zero from below as $t \to \infty$. □

A.2 Proof of Corollary 2

Point A in Figure 2 lies to the left of B if $(I_i(\bar{l}_h)/\underline{c})\big|_{t=t_{i,A}} < 1$, i.e., if $I_i(\bar{l}_h) < \underline{c}$ in point A. Horn becomes viable for women of strength ρ_i at point A: $w_h = w_{i,Fg}$. Using this in (17), we can solve for the land-labor ratio in horn: $\frac{t_h}{l_h} = \left[\rho_i \frac{\alpha_g}{\alpha_h}\left(\frac{A_g}{p_h A_h}\right)^{\frac{1}{\alpha_g}}\left(\frac{1-\alpha_g}{1-\alpha_h}\right)^{\frac{1-\alpha_g}{\alpha_g}}\right]^{\frac{\alpha_g}{\alpha_g-\alpha_h}}$, where $\alpha_g > \alpha_h$. Next, (3) simplifies to $I_i = w_{i,Fg}$ at point A. Using $w_{i,Fg} = \rho_i w_{Mg}$ and (16) yields: $I_i = \rho_i \alpha_g A_g \left(\frac{A_g}{p_h A_h}\frac{1-\alpha_g}{1-\alpha_h}\right)^{\frac{1-\alpha_g}{\alpha_g}}\left(\frac{t_h}{l_h}\right)^{\frac{\alpha_h}{\alpha_g}(1-\alpha_g)}$. Consequently, $I_i = \rho_i\alpha_g A_g\left[\left(\rho_i\frac{\alpha_g}{\alpha_h}\right)^{\alpha_h}\left(\frac{1-\alpha_g}{1-\alpha_h}\right)^{1-\alpha_h}\left(\frac{A_g}{p_h A_h}\right)\right]^{\frac{1-\alpha_g}{\alpha_g-\alpha_h}}$ at point A, which is increasing in ρ_i and A_g, and is decreasing in p_h and A_h. Therefore, conditions (i)-(iv) make $(I_i(\bar{l}_h)/\underline{c})\big|_{t=t_{i,A}} < 1$ more likely to hold. □

A.3 Strength-Dependent Female Labor in Horn $l_{i,h}$

This section shows how women across all strength types choose their labor supply in horn in response to changing land-labor ratios. This illustrates in detail the mechanism behind the aggregate labor supply shown in Figure 4. Throughout, we use the notation of points A and B introduced in Figure 2 (at the former, horn begins to offer a wage premium; at the latter, female income exceeds the threshold $\underline{c}$). We also take the price of horn p_h as given for now, and discuss implications of changing p_h at the end of this section. For ease of exposition, we refer to the line $w_h/w_{i,Fg}$ as "line A", and to $I_i(\bar{l}_h)/\underline{c}$ as "line B" – both as functions of the

[5]The latter holds because for all $t > t_{i,B}$: $I_i(\bar{l}_h) > \underline{c}$, and $\lim_{w_h\downarrow w_{i,Fg}} I_i(\bar{l}_h) = \lim_{w_h\downarrow w_{i,Fg}} w_{i,Fg} + \bar{l}_h(w_h - w_{i,Fg}) = w_{i,Fg}$.

[6]From footnote 5 we know that $w_{i,Fg} > \underline{c}$ at $t = t_{i,A}$, and (A.4) shows that $w_{i,Fg}$ is increasing in t. In addition, for $t > t_{i,A}$, $w_{i,Fg}/w_h < 1$.

land-labor ratio in horn t_h/l_h. Line A is defined by (17); it shifts downward if ρ_i increases. In contrast, line B is shifted upward for larger ρ_i (remember the definition $I_i(\bar{l}_h) = \rho_i w_{Mg}(1-\bar{l}_h) + w_h\bar{l}_h$). Consequently, increasing ρ_i moves point A to the right and point B to the left.

Next, we derive the strength $\rho_{A=B}$ at which points A and B coincide. First, at point A, $w_{i,Fg} = w_h$, so that we obtain for point B (if it is identical to A): $I_i(\bar{l}_h) = w_{i,Fg} = w_h = \underline{c}$. Therefore, we can use (12) to derive the land-labor ratio at which points A and B coincide:

$$\left.\frac{t_h}{l_h}\right|_{A=B} = \left(\frac{\underline{c}}{\alpha_h p_h A_h}\right)^{\frac{1}{1-\alpha_h}} \quad . \tag{A.8}$$

Second, because $w_{i,Fg} = \rho_i w_{Mg} = \underline{c}$, we can use (16) and (A.8) to obtain the strength ρ_i at which A and B are identical:

$$\rho_{A=B} = \underline{c} \Big/ \alpha_g A_g \left(\frac{A_g}{p_h A_h}\,\frac{1-\alpha_g}{1-\alpha_h}\right)^{\frac{1-\alpha_g}{\alpha_g}} \left(\left.\frac{t_h}{l_h}\right|_{A=B}\right)^{\frac{\alpha_h}{\alpha_g}(1-\alpha_g)} \quad . \tag{A.9}$$

For the following discussion, it is also useful to derive two more cutoffs: First, the maximum strength at which horn is still viable, ρ_A^{max}. For any given land-labor ratio, this is the strength at which $w_{i,Fg} = w_h$. Using (17), this is given by:

$$\rho_A^{\text{max}} = \frac{w_h}{w_{Mg}} = \frac{\alpha_h}{\alpha_g} \left(\frac{p_h A_h}{A_g}\right)^{\frac{1}{\alpha_g}} \left(\frac{1-\alpha_h}{1-\alpha_g}\right)^{\frac{1-\alpha_g}{\alpha_g}} \left(\frac{t_h}{l_h}\right)^{\frac{\alpha_g-\alpha_h}{\alpha_g}} \quad . \tag{A.10}$$

Note that ρ_A^{max} is increasing in the land-labor ratio. This is because $w_h/w_{i,Fg}$ grows with land abundance (Corollary 1), so that horn offers a wage premium for ever stronger women. Second, the cutoff ρ_B^{min} is the minimum strength at which female income exceeds the reference level $\underline{c}$. This is given by

$$\rho_B^{\text{min}} = \frac{\underline{c} - w_h\bar{l}_h}{w_{Mg}(1-\bar{l}_h)} \tag{A.11}$$

The cutoff strength ρ_B^{min} is decreasing in the land-labor ratio. Intuitively, ever weaker women can reach the consumption cutoff level $\underline{c}$ if land becomes more abundant so that wages surge.

Figure A.2 illustrates the female labor supply across all strength types, together with the probability density function $f(\rho)$, which is given by a beta distribution with both parameters equal to 2. In the first panel, we use a low land-labor ratio. In this setting, only a few low-strength women work in horn (to the left of ρ_A^{max}). For the remainder, horn wages do not offer a wage premium. At the same time, ρ_B^{min} is to the right of ρ_A^{max}, so that all women who can earn a wages premium in horn have consumption below the reference level $\underline{c}$, and thus work the maximum amount $\bar{l}_h$. If the land-labor ratio increases, ρ_A^{max} rises while ρ_B^{min} declines. Consequently, there must be an l_h/t_h such that both coincide. This is exactly the ratio given by (A.8), and the corresponding strength is $\rho_{A=B}$. We use this land-labor ratio in the second panel of Figure A.2. The point $\rho_{A=B}$ corresponds to the kink in the aggregate horn labor supply, as shown in Figure 4 in the paper. It is the highest strength at which women behave according to EMP.[7] When this point coincides with $\rho_A^{\max}$ and $\rho_B^{\min}$, women with strength $\rho_i < \rho_{A=B}$ work the maximum time $\bar{l}_h$ in horn, and women with strength $\rho_i > \rho_{A=B}$ do not work in horn, at all.

If the land-labor ratio increases further (third panel in Figure A.2), $\rho_A^{\max}$ moves to the right of $\rho_B^{\min}$. Women with strength between $\rho_{A=B}$ and $\rho_A^{\max}$ do not work in horn because their income is well above the reference level $\underline{c}$, while the wage premium they would earn in horn is relatively small.[8] For women with strength between $\rho_B^{\min}$ and $\rho_{A=B}$, income now exceeds the threshold level, and the income effect implies that they provide relatively less labor in horn in order to have more children. Finally, for women the the left of $\rho_B^{\min}$ income is below $\underline{c}$, so that they work the maximum possible time in horn.

In sum, an increase in the land-labor ratio from just-below $\rho_{A=B}$ to just-above this point implies that a) no additional women are drawn into the horn sector; and b) the strongest among those who do work in horn now work less. This explains the kink in aggregate labor supply (Figure 4).

What if we take into account a demand effect such that p_h increases with the land-labor ratio (as with the non-homothetic demand in Section 3.6)? This effect unambiguously strengthens the emergence of EMP. First, according to (A.8) and (A.9), $\rho_{A=B}$ increases with p_h. Therefore, a larger fraction of women can earn a wage premium in horn. Second, following (A.10), $\rho_A^{\max}$ increases in p_h, which also results in higher female labor in horn (see the first panel in Figure A.2). Because of these two effects, the initial increase in aggregate horn labor supply (and thus the drop in fertility – see Figure 4) is steeper. Finally, (A.11) implies that $\rho_B^{\min}$ is falling in p_h (because the latter raises w_h). This becomes important for relatively high land-labor ratios, when $\rho_B^{\min} < \rho_A^{\max}$. As illustrated in the third panel of Figure A.2, a decline in $\rho_B^{\min}$ means that more women reduce their working time in horn in response to growing income. Thus, birth rates are more responsive to income. To sum up, if horn is a luxury product, the initial drop in fertility is steeper, and the subsequent positive response of birth rates to income is also more pronounced.

A.4 Stone-Geary Preferences

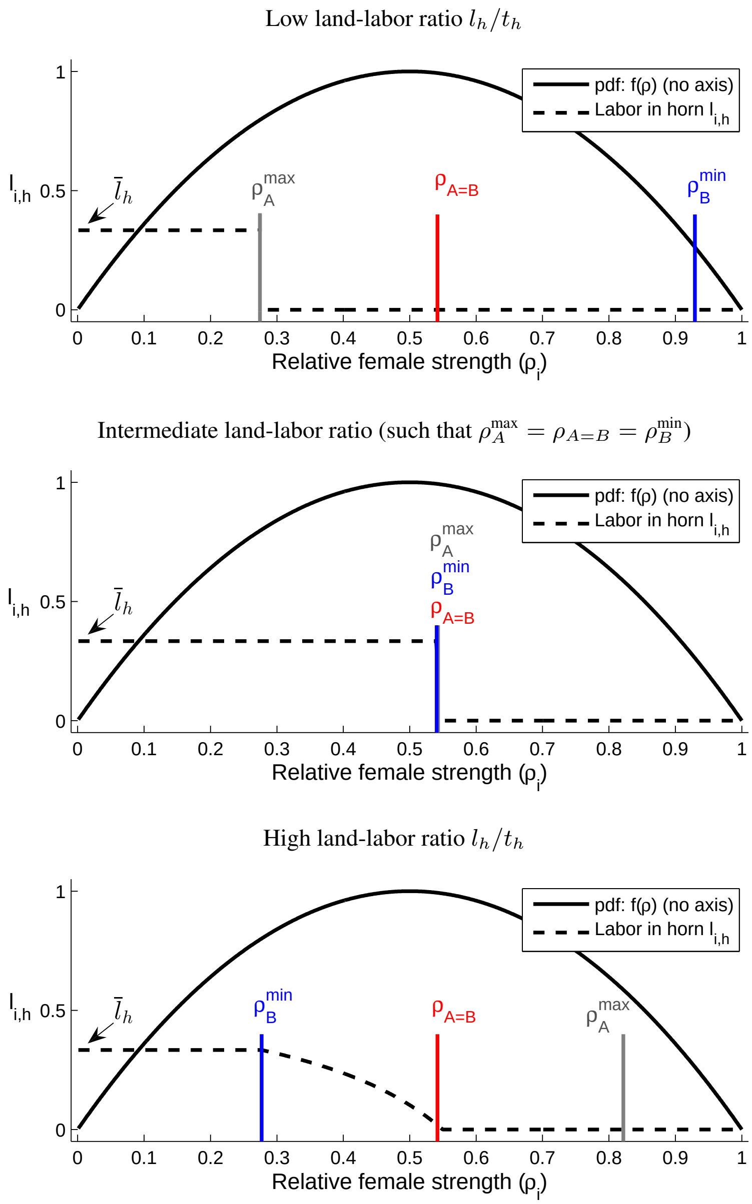
This section discusses our Stone-Geary consumption preferences in detail and shows that they imply an indirect utility in line with equation (2) in the paper. Before individuals buy the 'luxury' horn products, they need to satisfy their basic nutritional requirement $\underline{c}$ with grain consumption. Below this reference level, any increase in income is spent on grain. Preferences take the Stone-Geary form:

$$h(c_{i,g}, c_{i,h}) = \begin{cases} \ln\left((c_{i,g} - \underline{c} + \epsilon)^{\phi} c_{i,h}^{1-\phi}\right), & \text{if } c_{i,g} > \underline{c} \\ (c_{i,g} - \underline{c})/\epsilon + \ln(\epsilon), & \text{if } c_{i,g} \leq \underline{c} \end{cases} \quad \text{(A.12)}$$

[7] For large land-labor ratios, women with strength close to but above $\rho_{A=B}$ also work in horn (albeit very little – see the proof in appendix A.1). However, their fertility is *decreasing* in the land-labor ratio and is thus incompatible with feature (ii) of EMP. Thus, the relevant strength range for EMP is to the left of $\rho_{A=B}$.

[8] The (opportunity) cost of children is so low for these women, that they would like to give up consumption in order to 'buy time' and have more children. This is the case explained in footnote 33 in the paper.

Figure A.2: Female labor in horn $l_{i,h}$ as a function of strength ρ_i, for low, middle, and high land-labor ratios



Notes: $\rho_A^{\max}$ is the maximum strength at which horn is still viable (i.e., offers a wage premium), given the land-labor ratio l_h/t_h. $\rho_B^{\min}$ is the minimum strength at which female income exceeds the reference level $\underline{c}$, given the land-labor ratio. $\rho_{A=B}$ is the strength at which points A and B coincide (see equation (A.9)).

where $\phi > 0$ is a constant and ϵ is infinitesimal. Given income I_i (for women) or w_{Mg} (for men), consumers maximize (A.12) subject to their budget constraint $c_{i,g} + p_h c_{i,h} \leq I_i$.[9] When $I_i \leq \underline{c}$, the (trivial) solution is $c_{i,g} = I_i$. For $I_i > \underline{c}$, optimization yields the expenditure shares given by (20), when ignoring the infinitesimal ϵ. Re-arranging the expenditure shares and substituting in the first line of (A.12) we obtain the indirect utility:

$$\widetilde{h}(I_i, p_h) = \begin{cases} \ln\left(I_i - \underline{c} + \epsilon\right) + \ln\left(\phi^{\phi}\left(\frac{1-\phi}{p_h}\right)^{1-\phi}\right), & \text{if } I_i > \underline{c} \\ (I_i - \underline{c})/\epsilon + \ln(\epsilon), & \text{if } I_i \leq \underline{c} \end{cases} \tag{A.13}$$

Individual female and male peasants take the price of horn as given; they also spend all their income on consumption, so that p_h does not affect intertemporal allocation. Therefore, the second term in parentheses for the case $I_i > \underline{c}$ in (A.13) does not affect individual decision making (i.e., it does not influence the *marginal* utility of consumption). Consequently, the indirect utility given by (A.13) implies the same optimal choices of consumption and fertility as the form given by (2) in the paper.

A.5 Solving the Model

In this section, we describe how we solve our model in general equilibrium. We begin by solving the model for wages, labor supply, and birth rates for *given* land-labor ratios $t = T/N$. The steady state level of t (or more precisely, N, because T is fixed) is then determined by the intersection of birth and death rates, as shown in Figure.

Before describing the solution algorithm, we explain the equations that it uses. Consumption of an *average* peasant household over the adult period is given by

$$\begin{aligned} c_g^p &= c_{Mg} + \int_0^1 \rho_i \cdot c_{i,g}(\rho_i) f(\rho_i) d\rho_i \\ c_h^p &= c_{Mh} + \int_0^1 \rho_i \cdot c_{i,h}(\rho_i) f(\rho_i) d\rho_i \, , \end{aligned} \tag{A.14}$$

where c_{Mg} and c_{Mh} are male grain and horn consumption, respectively, as given by (20) for the male wage w_{Mg}. Multiplying these by N yields aggregate peasant consumption.

Next, we derive a system of three equations that solves for the three unknowns w_{Mg}, w_h, and t_h. This involves market clearing. Because the landlord spends his income on non-agricultural items (such as warfare), the relevant market clearing condition refers to the peasant part of consumption and production only.[10]

$$N(\widehat{l_g} w_{Mg} + l_h w_h) = \alpha Y_g + \alpha_h p_h Y_h \, . \tag{A.15}$$

[9] We model the female optimization only. All results also hold for male peasants, where the index i is not needed because men are homogeneous.

[10] One can use an alternative setup with equivalent implications: That the landlord has the same consumption preferences as peasants. Historically, this alternative assumption is reasonable: While land-owners themselves did not consume goods in the same proportions as peasants, the staff they employed in large numbers, or the armies they maintained, did. In this alternative setting, (A.15) is given by $N(\widehat{l_g} w_{Mg} + l_h w_h) + rT = Y_g + p_h Y_h$. This yields identical results.

Dividing by N and using (8), (9), and $t_g = t - t_h$ yields:

$$\widehat{l}_g w_{Mg} + l_h w_h = \alpha A_g \widehat{l}_g^{\alpha_g} (t - t_h)^{1-\alpha_g} + \alpha_h p_h A_h l_h^{\alpha_h} t_h^{1-\alpha_h} \ . \tag{A.16}$$

This is the first equation in our system of three. The remaining two are (12) and (13). For a given price of horn p_h and land per household t, as well as labor supply l_h and $\widehat{l}_g$, we can solve this system of equations to obtain w_{Mg}, w_h, and t_h. This solution is for the case where the horn sector operates, i.e., where $l_h > 0$ and $c_h^p > 0$. If the horn sector does not operate, equation (A.16) is replaced by $t_h = 0$. This also yields $w_h = 0$ in (12), and (13) then uses $t_g = t$.

We have now specified all equations that we need to solve for the general equilibrium. Starting from initial guesses for w_h, w_{Mg}, p_h, and t_h, our algorithm to solve the model then follows the steps:

1. Obtain individual birth rates b_i and individual female labor supply $l_{i,h}$ for *given* wages and p_h from (18) and (19).

2. Use (20) to calculate individual demand, given p_h and I_i (the latter is obtain from (3) for given wages)

3. Aggregate across all strength types to obtain $\widehat{l}_g$ from (11), $l_h = \int_0^1 l_{i,h}(\rho_i) f(\rho_i) d\rho_i$, as well as aggregate peasant consumption $C_g^p = N c_g^p$ and $C_h^p = N c_h^p$ from (A.14)

4. For the derived $\widehat{l}_g$ and l_h (and given t_h), calculate the aggregate output of horn, Y_h from (8) and grain, Y_g, from (9). Derive the part of production that goes to peasants as $Y_h^p = \alpha_h p_h Y_h$ and $Y_g^p = \alpha_g Y_g$.

5. Update the price to p'_h: If $Y_h^p > C_h^p$, then $p'_h < p_h$, and vice versa.

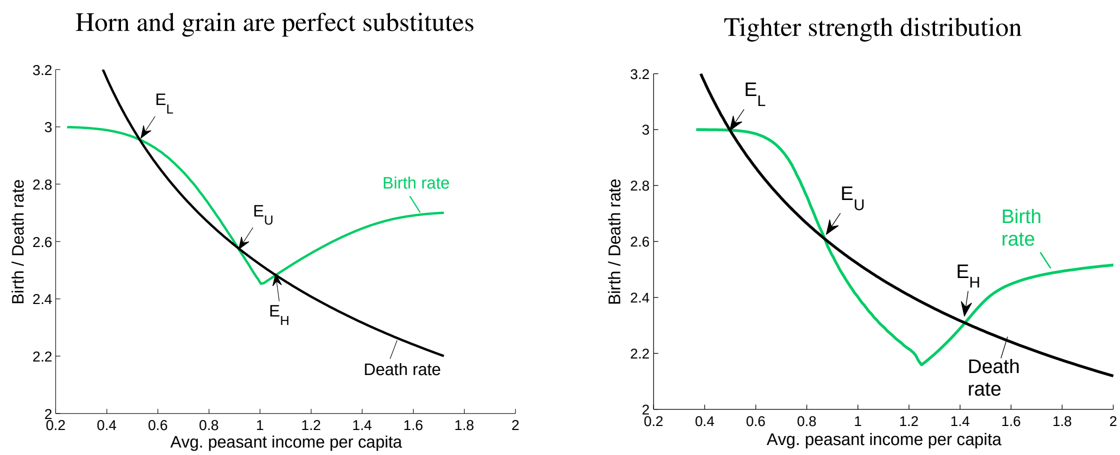
6. Solve the system of three equations (12), (13), and (A.15) for given p'_h, This delivers updated wages w'_h and w'_{Mg}, as well as the land per household in horn t'_h.

We run this loop until the maximum absolute deviation between the four original and updated values is below a small positive number. Note that birth rates are not needed in the solution algorithm, because it solves the model for a given land per household t. However, aggregate (average) fertility determines the Malthusian equilibria as in Figure 5, and thus t. It is derived from individual birth rates (see step 1) by integrating across all types: $b = \int_0^1 b_i(\rho_i) f(\rho_i) d\rho_i$. Similarly, the death rate follows from average peasant consumption $\bar{c}^p$ and is given by equation (6). We calculate $\bar{c}^p = \int_0^1 c_i^p(\rho_i) f(\rho_i) d\rho_i$, where $c_i^p = \bar{p}_h c_{i,h} + c_{i,g}$, is a measure of real income, with the price of horn held constant at the level $\bar{p}_h$, measured in the equilibrium E_L (see the left panel of 5).

A.6 Robustness Checks of the Model

In this section, we analyze the robustness of our model to alternative parameter choices. The left panel of Figure A.3 shows the simulation results without the demand effect for 'luxury' horn products. Here, we model the case where horn and grain are perfect substitutes, normalizing $p_h = 1$. We use the same parameters as in the baseline model.[11] As the figure shows, the emergence of EMP is slightly dampened: The drop in fertility rate is now smaller than in the baseline model (Figure 5 in the paper). However, we still obtain the two stable steady states E_L and E_H. In the right panel of Figure A.3, we show that our results are robust to using a tighter distribution. Here, we use a beta distribution with both parameters equal to 5, so that the mean is still 0.5, but the standard deviation is now 0.15 (instead of 0.22). The results are very similar to those obtained in our baseline model.

Figure A.3: Model Robustness – Perfect Substitutes and Strength Distribution



Note: In the left panel, we assume that horn and grain products are perfectly substitutable, so that $p_h = 1$. In the right panel, we use a tighter strength beta distribution $f(\rho)$, with both parameters set equal to 5 (instead of 2).

While the slope of the death schedule (the strength of the "positive Malthusian check") does not affect our main mechanism, it influences the location (and existence) of the high-income steady state E_H. In our baseline simulation, we use an elasticity of death rates with respect to income of -0.25. This is the average estimate for England between 1600 and 1800 by Kelly and Ó Grada (2010). Kelly and Ó Grada argue that in early modern England, the positive check may have been dampened by the Old Poor Law. When we use an elasticity of -0.5 instead, we still obtain both steady states, but yet more negative elasticities result in a unique steady state E_L. Nevertheless, warfare and epidemics after 1400 arguably shifted the death schedule upward (Voigtländer and Voth, 2013). Once we account for this *shift* in the death rate, even elasticities below -0.5 deliver multiple steady states. At the other extreme, Anderson and Lee (2002) document elasticities of mortality between -0.076 and -0.16 for 16C–19C England and Europe. When using these values, we always obtain multiple steady states with larger income levels in E_H, thus strengthening the impact of EMP.

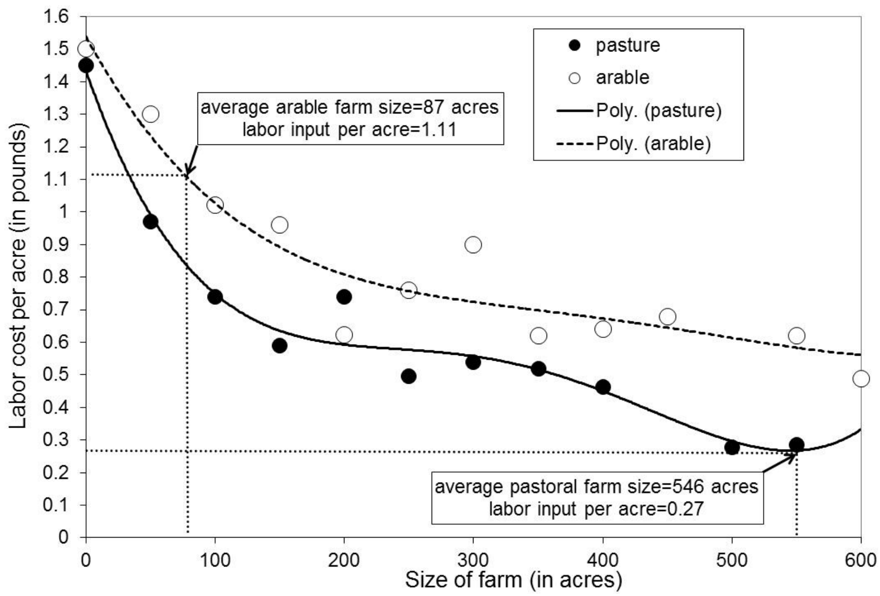
[11] There is one exception: A_h now has double its original value. This compensates for the fact that in the baseline simulation p_h was approximately 2 in the equilibrium E_H.

B Empirical Appendix

B.1 Labor Cost and Female Labor in Pastoral and Arable Farming

Allen (1988) calculates labor cost per acre for pastoral and arable farms (tables 8 and 9). We plot his data in figure B.1. The average farm size is calculated from Allen (1988, Table 4). The size distribution of farms is from Table 4 in Allen (1988). Conservatively, we assume that farms listed as having 1,000+ acres (which are all pastoral) had an average size of 1,000 acres. This means that the estimated average size for pastoral farms is a lower bound of the true value.

Figure B.1: Arable and pastoral labor cost per acre, by farms size



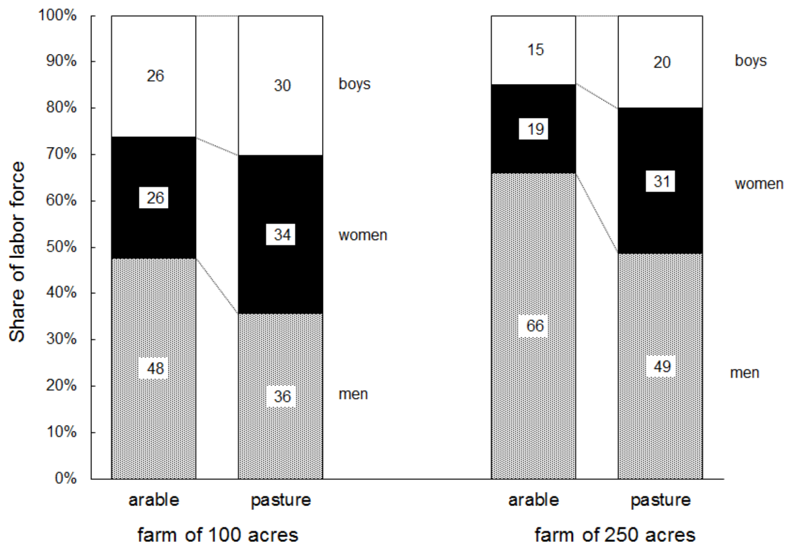
Notes: Data source: Allen (1988). The figure shows individual observations and a fourth-degree polynomial for each farm type.

Figure B.2 shows that switching from arable to pastoral farming resulted in a more important role for female labor.

B.2 Sexual Division of Labor – Anthropological Evidence

Does the anthropological literature on work patterns support the notion that pastoral activities are more compatible with female labor? To answer this question, we examine the data on 185 societies compiled by Murdock and Provost (1973). They classify each activity according to the extent to which it uses male or female labor. To take one example, the hunting of large aquatic animals is classified as an exclusively male activity in the 48 tribes where it is observed. At the opposite end of the spectrum, in 174 societies

Figure B.2: Labor Usage on Arable and Pastoral Farms, by Size of Farm

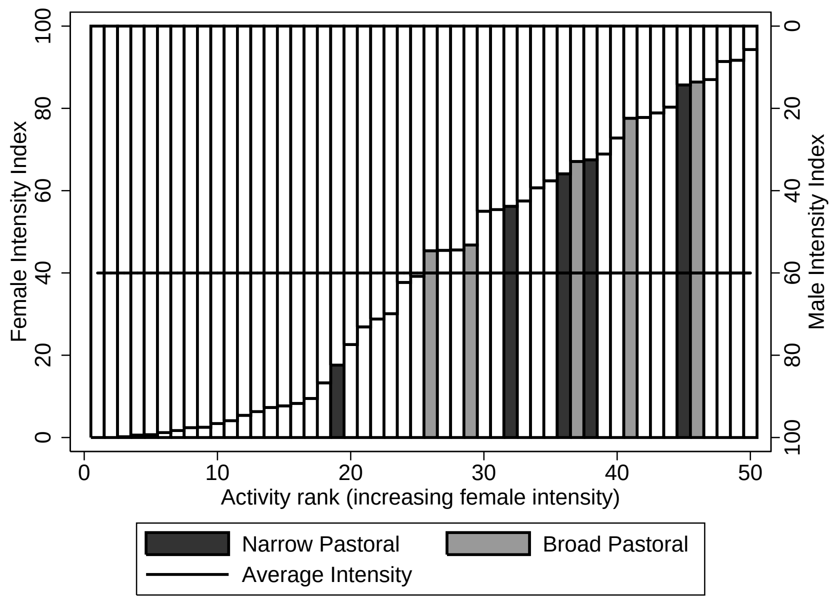


Data source: Allen (1991, Table 9.4).

where there is information on the preparation of vegetal foods, fully 145 (83%) only used female labor for the purpose. Most activities fall between these two extremes. Murdock and Provost assign a letter for each tribe and activity: M – exclusively male; N – dominantly male; E – equal participation; G – dominantly (but not exclusively) female; F – exclusively female. They then compile an index of male labor intensity, which takes values between 0 and 100, using weights of $M = 1$; $N = 0.8$; $E = 0.5$; $G = 0.2$; $F = 0$. We invert it by taking the female activity index as 100–male activity index. The result is plotted in Figure B.3. The most male activities are on the left; the most female-labor intensive tasks are on the right of the spectrum. Pastoral activities such as looking after small and large animals, milking, etc. are highlighted in black ('Narrow Pastoral'); pasture-related activities are grey ('Broad Pastoral'). As is readily apparent, pastoral activities use ample female labor – they are far to the right in the distribution. All of them except one use female labor more intensively than the average activity sampled by ethnographers.

Next, we perform regression analysis, using both the female activity index and the ranking of activities as dependent variables. As explanatory variables, we first use a dummy for the broader set of pastoral and pastoral-related activities ($Pastoral^{\text{broad}}$). In addition, we restrict the analysis to strictly pastoral activities ($Pastoral^{\text{narrow}}$). Table B.1 gives the results. We find strongly significant relationships for most combinations of dependent and explanatory variables. For example, the result in column 1 suggests that on a scale from 0–100, pastoral activities score on average 64.7; non-pastoral activities have an average score of 37.3, a difference of 27.4. If we exclude the pastoral-related activities (column 2), the coefficient drops to 20.3, but is still significant at the 10% level. When we use the rank as the dependent variable (columns 3-4), the result is the same – pastoral activities score much higher than non-pastoral activities in their intensity of

Figure B.3: Intensity of female labor usage, by activity



Notes: Data source: Murdock and Provost (1973). Pastoral activities (narrowly defined) include 'tending large animals', 'milking', 'care of small animals', 'loom weaving', and 'dairy production'. Pastoral activities (broadly defined) additionally include 'preparation of skins', 'manufacture of leather products', 'preservation of meat and fish', 'manufacture of clothing', and 'spinning'.

using female labor.

Table B.1: Anthropological evidence: Female labor intensity of pastoral activities

	(1)	(2)	(3)	(4)
Dep. Var.:	Female Intensity Index		Female Intensity Rank	
$Pastoral^{\text{broad}}$	27.41***		11.44***	
	(8.926)		(4.045)	
$Pastoral^{\text{narrow}}$		20.26*		9.444**
		(11.38)		(4.514)
Constant	37.25***	37.96***	24.36***	24.56***
	(4.899)	(4.917)	(2.216)	
R^2	.066	.036	.057	.039
Observations	50	50	50	50

Notes: Robust standard errors in parentheses. Key: *** significant at 1%; ** 5%; * 10%. Data from Murdock and Provost (1973). $Pastoral^{\text{broad}}$ and $Pastoral^{\text{narrow}}$ are dummies for broad and narrowly defined pastoral activities, respectively. See the note to Figure B.3 for a list of these activities.

In combination, these results strongly suggest that pastoral agriculture is more intensive in the use of female labor than other farming activities. A similar conclusion emerges if we use information on patterns of time-use in different farming activities. Minge-Klevana (1980) collect evidence on working hours in 15 agricultural societies. Where pastoralism is mentioned as at least one of the forms of cultivation (5 societies), working hours for women are markedly longer – 11 hours per day, vs 8.4 hours in the rest of the sample (the difference is statistically significant at the 10% level).

B.3 Background on Demography and Agriculture in China

The extent to which Chinese demography resulted in higher fertility and greater pressure on living standards is debated. As Lee and Feng (1999) and Feng, Lee, and Campbell (1995) have argued, infanticide and lower fertility limitation within marriage reduced population growth rates. However, what matters for population pressure is the total fertility rate – the combined effect of marriage rates and fertility within marriage. There is no question that this rate was markedly higher in China than in Europe – by 20-40% (Smith, 2011). In line with this, 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 (Maddison, 2001). In other words, Chinese population growth was approximately one third faster than in Europe.

Grain production in China was approximately 4 times more efficient than in England. We use the figures by Allen (2009) on output per acre and output per day, weighting them with a labor share of 0.5.[12] Chinese land productivity was 700% of English land productivity in grain, and labor productivity was 86%. This implies a factor-weighted average of 392%. The main reason for high land productivity was the limited size of plots: Chinese farms were markedly smaller, and labor input per acre much higher, than in England.

[12]From his figures, we derive an estimate of output per acre in arable farming in the midlands of 3.5 pounds per acre.

Continuous population pressure led to increasing subdivision of farms. Table B.2 compares farm sizes in the most advanced areas – England and the Yangtze Delta. At the dawn of the nineteenth century, English farms were thus, on average, 150 times larger than Yangtze ones.

Table B.2: 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).

Chinese grain production was efficient because it used various techniques to raise output per unit of land. All of them required the use of more labor – rice paddy cultivation, the use of bean cake as fertilizer, and intercropping with wheat (Goldstone, 2003; Brenner and Isett, 2002). The relatively low productivity of grain agriculture in England is reflected in its low share in land use. Arable production accounted for only 39-43% of acreage in England, according to Broadberry, Campbell, and van Leeuwen (2011, Table 3). In contrast, rice and grain accounted for almost all of China's land use.

Chinese farms used all means available to raise output per unit of land; the same is not true of output per worker. Ever fewer draft animals were in use. While Chinese 16th century writers observed that "the labor of ten men equals that of one ox,"[13] the use of draft animals declined in the Ming (1368-1644) and Qing (1644-1911) period. By the mid-Qing period, animal use had disappeared almost entirely, except for the most arduous tasks.[14] The land needed to feed an ox was dear, and farms were typically too small for keeping an ox.

Ever smaller farm sizes in China also meant that there was less scope for female employment in agriculture. Labor requirements could be satisfied by the existing male labor force on 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 market wages were only 25% of male wages in 1820s China, whereas English women's market wages were equivalent to 50-63% of English male wages (Kussmaul, 1981; Allen, 2009).[15] This offers

[13] Cited after Brenner and Isett (2002).

[14] The view is controversial. Wider availability of bean cake may have helped the increased use of oxen after 1620 (Allen, 2009).

[15] In our model, female market wages are represented by w_h. Low w_h/w_{Mg} is thus an indicator for relatively high productivity

important empirical support for the predictions of our model - in Europe, female labor was relatively more valuable, partly because technology, soil, and climate favored the pastoralism, where women could make more of a contribution.

B.4 Comparison of Marital Fertility Rates

This section compares fertility within marriage for Hutterites, Western Europe before 1800, and China. Table B.3 shows that European marital fertility was only slightly below contemporaneous levels of Hutterites and therefore probably close to the biological maximum.[16]

Table B.3: Marital fertility rates (births per year and woman)

Age	Hutterites	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).

B.5 Measures for Pastoral Production and Instrumental Variables

In this section we check the consistency of our measure for pastoral production at the English county level in 1290, and describe the construction of our instrumental variable, the days of the year during which grass grows.

Arable Acreage in 1290

Because the share of pastoral land is not available for medieval times, we use the proxy $Pastoral^{1290}$ = 1–share of arable land in 1290. We take the share of arable land in 1290 from Table 7 in Broadberry et al. (2011). In the following we show that this proxy performs well. We first construct the same variable for 1836 – when more detailed data on land use are available – and compare it to the actual share of pastoral land. Kain (1986) reports four categories: arable land, woodland, grassland, commons, for 28 counties in 1836. In an average county, these account for 97.8% of county acreage. Grassland and commons (which were mostly pastures) reflect pastoral land. We plot this against 1–share of arable land in 1836 in the left panel of Figure B.4. The fit is very good, and, importantly, there is no systematic bias (deviation from the 45-degree line) in our proxy.

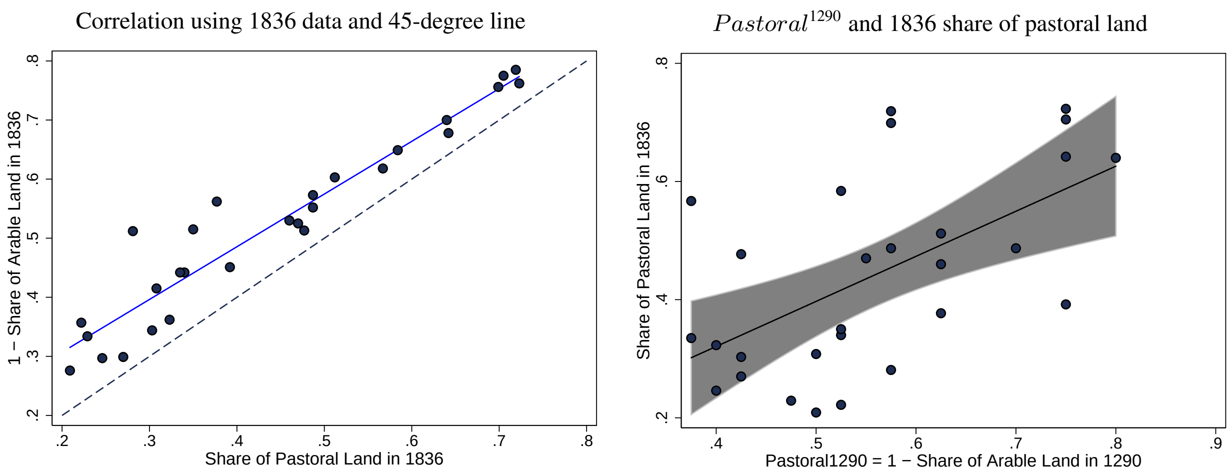
Next, we analyze how strongly our main explanatory variable $Pastoral^{1290}$ itself is correlated with

in grain (i.e., small A_h/A_g in China).

[16] The remaining minor difference is at least partially explained by the better nutrition and general health of Hutterites.

the share of pastoral land in 1836. The right panel of Figure B.4 shows the relationship. The correlation coefficient is .58, significant at the 1% level.

Figure B.4: Consistency check of the variable $Pastoral^{1290}$



Source: County level data for 1836 are from Kain (1986), who reports four categories: arable land, grassland, commons, and woodland. We use the combined share of grassland and commons as the share of pastoral land in 1836. County-level arable acreage in 1290 is calculated as 1–share of arable land in 1290, which is from Broadberry et al. (2011).

Finally, we verify that more pastoral *land* in a county also implies more pastoral *production*.[17] Data on livestock at the county level in 1867 from Mingay and Thirsk (2011) suggest a strong positive relationship (Figure B.5).

Grass growing days

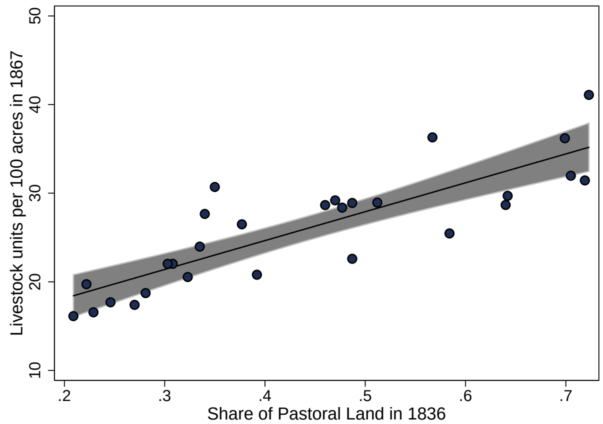
We use days of grass growth ($daysgrass$) from Down, Jollans, Lazenby, and Wilkins (1981) to instrument for the suitability for pastoral agriculture. Grass growing days are derived based on suitable soil temperature (above 6 degrees Celsius), adjusted for a drought factor and altitude. Figure B.6 plots the number of days of grass growth in a typical year in the British Isles. While the broad pattern is of higher suitability to the West, there is substantial variation even at relatively low levels of aggregation.

In Figure B.7 we show that $\ln(daysgrass)$ is a strong predictor of the share of pastoral land in 1290. The left panel of the figure depicts the raw correlation, while the right panel shows a partial scatterplot, after controlling for general crop suitability for agriculture. The latter is calculated following Alesina, Giuliano, and Nunn (2011). We first define land as "suitable" for a crop (wheat, barley, or rye) if it reaches a yield/ha at least 40% of the maximum observed yield.[18] We then calculate county-level crop suitability as the share of each county's land area that is "suitable" for at least one crop according to the 40% cutoff.

[17] One concern is that grassland and commons may merely reflect fallow land.

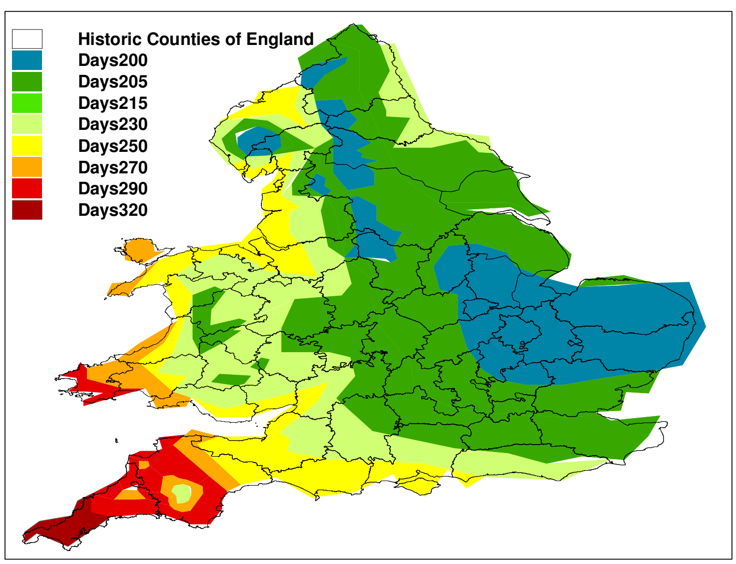
[18] Soil suitability for each crop is from Gaez 3.0 (FAO/IIASA, 2010), derived for low inputs (traditional farming technology) and rain-fed agriculture (no irrigation). This best reflects the conditions of early modern agriculture.

Figure B.5: Regions with more Grass and Commons have more Livestock



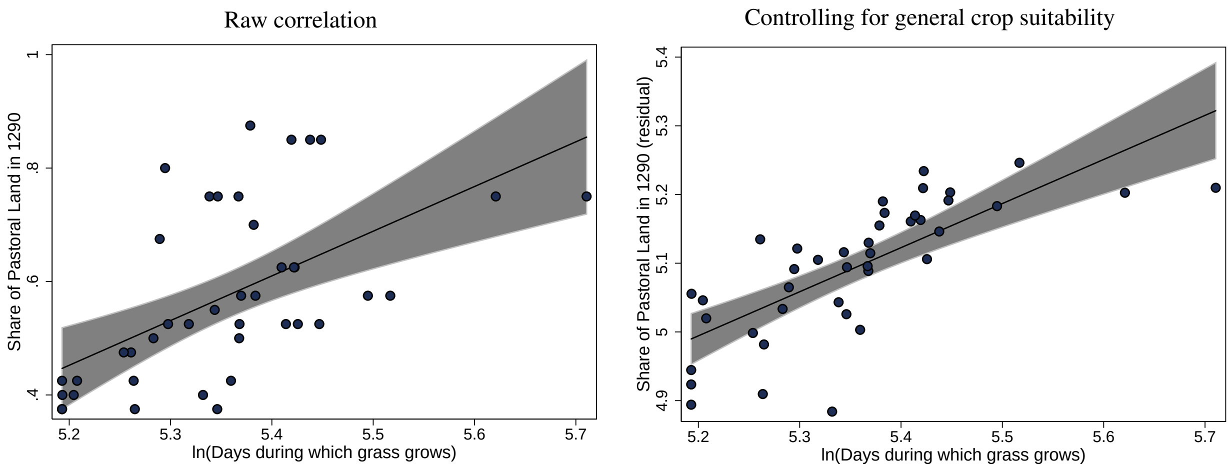
Source: Data on livestock at the county level in 1867 is from The Agrarian History of England and Wales, vol. VI (Mingay and Thirsk, 2011), Table III.10. One unit of livestock reflects 1 cow/ox, or 7 sheep. See note to Table B.4 for the share of pastoral land in 1836.

Figure B.6: Days of Grass Growth



Source: Data from Down et al. (1981).

Figure B.7: First stage using days of grass growth as IV for pastoral land



Source: The number of days during which grass grows is from Down et al. (1981). County-level arable acreage in 1290 is from Broadberry et al. (2011). General crop suitability is derived from FAO/IIASA (2010), following Alesina et al. (2011).

Table B.4 shows the corresponding first-stage regressions for both $Pastoral^{1290}$ and $Pastoral^{1836}$ as dependent variable. Our instrument $\ln(daysgrass)$ is a strong and robust predictor of pastoral land shares. As one should expect, general crop suitability is negatively correlated with pastoral land use. None of our IV results depends on whether we control for general grain feasibility. All results presented in the paper use only $\ln(daysgrass)$. This is shown in Table B.5, which replicates the estimates from the paper, including general crop suitability in the first stage.

Table B.4: First stage regressions

	(1)	(2)	(3)	(4)
Dep. Var.:	$Pastoral^{1290}$		$Pastoral^{1836}$	
$\ln(daysgrass)$	.788***	.545***	.808***	.652**
	(.135)	(.163)	(.185)	(.252)
General Crop Suitability		-.279***		-.189*
		(.067)		(.108)
R^2	.328	.569	.344	.422
Observations	41	41	28	28

Notes: Robust standard errors in parentheses. Key: *** significant at 1%; ** 5%; * 10%. The number of days during which grass grows is from Down et al. (1981). County-level arable acreage in 1290 is from Broadberry et al. (2011). General crop suitability is derived from FAO/IIASA (2010) as described in the text.

Table B.5: Main IV results, using general crop suitability as additional instrument

	(1)	(2)	(3)	(4)	(5)
Table (T.), Column (col.):	T.3, col.4	T.4, col.3	T.4, col.6	T.5, col.3	T.5, col.4
$Pastoral^{1290}$	1.045***	5.130**	4.985**		
	(0.147)	(2.252)	(2.508)		
DMV		6.813**	7.098**		
		(2.684)	(3.125)		
$PastoralMarriage$				7.321***	7.130***
				(1.765)	(1.909)
Period FE	-	yes	yes	yes	yes
Observations	38	112	66	112	66
First Stage F-Statistic#	18.9	33.2	30.6	41.6	16.5

Notes: The table replicates the IV regressions reported in the paper, using 2 instruments: 1) The number of days during which grass grows (from Down et al. (1981)), and 2) general crop suitability (derived from FAO/IIASA (2010) as described in the text). The second row in this table indicates which regression from the paper is replicated. Robust standard errors in parentheses (in columns 2-5 clustered at the county level). Key: *** significant at 1%; ** 5%; * 10%.
Kleibergen-Paap rK Wald F statistic.

B.6 Evidence from the 1377 and 1381 Poll Tax: Sampling Procedure and Results

This section describes our use of the poll tax returns of 1377-81 as an indicator of the number of unmarried women. We begin by explaining our sampling procedure and then turn to the empirical approach and results.

Sampling Procedure

Ideally, we would like to have direct information on the number of unmarried women in 1377 and 1381. For 1377, the surviving rolls are not complete enough to determine this for a country-wide sample.[19] Instead, we do two things. First, we calculate the drop in the number of taxpayers between 1377 (when evasion was minimal) and 1381 (when it was massive). The 1381 rolls are more complete, and we collect direct information on marital status of the assessed population for this year. This procedure shows that in those areas where there are many "missing women" in the 1381 tax returns, relative to 1377, there is also a suspiciously high number of unmarried men relative to unmarried women.

Medieval England was subdivided into either hundreds, wapentakes, or liberties, depending on the local naming convention. Below this level, the parish or vill formed the smallest administrative unit. The Exchequer named county-level commissions, which in turn appointed local collectors in charge of assessing and collecting the tax dues in a given area (usually a small number of vills or parishes).

The collectors would then turn over proceeds and tax rolls to the county commission. Tax rolls contain the names of each taxpayer, the amount taxed, and the parish or vill where the taxpayer was assessed. Marital status and occupation were recorded at the discretion of the individual tax collector.

[19] Only seven counties have surviving nominative rolls in 1377, and these contain little information.

These tax rolls (also called nominative rolls) were checked and aggregated at the county level, with extracts (particulars of account) sent to London along with the proceeds of the collection. These generally included a list of all settlements in the county with their respective number of taxpayers and taxed amount. Sometimes the aggregation was conducted at the hundred level, rather than that of the individual vill or parish.

Surviving data on the Poll Taxes either comes from the nominative rolls or the particulars of account (Fenwick, 1998, 2001, 2005). In the former case, information on sex and marital status might be available. The latter only contain aggregate information on the number of taxpayers and amounts collected. In 1381, no account particulars were compiled.

The sampling was performed by first eliminating all counties for which no nominative rolls remained for the 1381 Poll Tax. Then, the number of settlements in each county with usable data was determined. A settlement was included in the sampling pool if it satisfied the following criteria: 1. It showed the presence of at least one married couple (thus eliminating records where marital status was not recorded). 2. It was complete, or, only a few centimeters of the medieval tax roll was missing, with no discernible pattern in the sequence of entries for married and unmarried people (i.e., missing individuals would not skew the sampling).

From the remaining settlements, a maximum of ten settlements were picked at random for each county (using the Excel random number generator). For counties where records from fewer than ten settlements survived, all available settlements were sampled. The sex was determined from either the name, or from the occupation (in the case of individuals with faded first names), when it unambiguously indicates gender (e.g., "milkmaid").

The nominative rolls used two different conventions for recording marital status. In the first, the names of all men, and only unmarried women were recorded. The wives present were tallied by adding "ux." next to the name of their husband [from Latin uxor, wife]. In other rolls, names for all taxpayers are recorded, with each wife listed after their husband, followed by "Ux. Eius" ["His wife"]. In each of these cases, the number of married couples and of unmarried men and women can easily be calculated.

The Cities of London and York were not considered part of any county for taxation purposes. Where the records for a county included one or more cities, at least one was sampled in each case in addition to the ten rural settlements. For Canterbury, a large city (2,200 taxpayers) with no division into parishes, ten randomly selected blocks of 45 people were sampled.

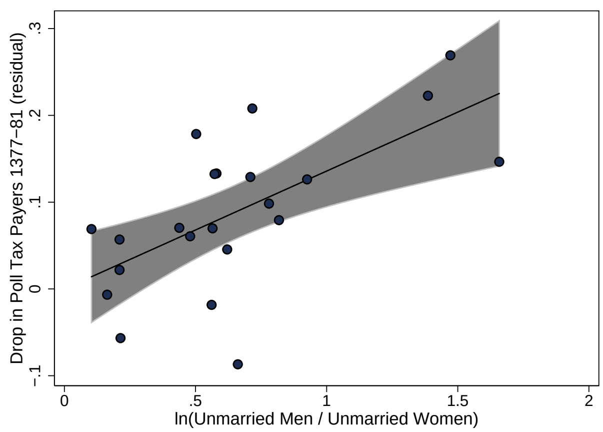
The end result is a dataset of 193 vill/parish records from 22 counties. Table B.9 at the end of this appendix shows the list of sampled settlements and the sample number of people living in each settlement. There are 17 counties with the full complement of ten sampled settlements. Somerset has only nine, Northamptonshire has seven, and Kent, Worcestershire and Sussex only have records for one city each (Canterbury, Worcester and Chichester respectively).

Empirical Approach and Results

We construct two variables from the poll tax returns of 1377 and 1381. Fenwick (1998, 2001, 2005) provides transcriptions of the names and assessed amounts of tax payers for each sub-county ("hundred", where they survived), as well as county totals (of which a substantially larger number is available). The drop in the number of taxpayers is calculated from changes in the total number of assessed individuals in 1377 and 1381. For example, in south-east Lincolnshire, the sub-division of Holland returned 18,592 taxpayers in 1377. In 1381, only 13,519 appear as taxed, equivalent to a drop of 27 percent (Fenwick, 2001, p. 3). We construct the percentage drop in tax payers between 1377–81 ($\%TaxDrop$) for 38 English counties.[20]

To verify that 'missing women' are indeed an explanation for the drop in tax payers, we use our sample of 193 settlements from 22 counties where individual tax records survived, as explained above (Fenwick, 1998, 2001, 2005). We count the number of unmarried men (M_{single}) and women (W_{single}). This allows us to construct a measure for 'missing single women' (following Oman, 1906): $\ln\left(M_{\text{single}}/W_{\text{single}}\right)$. This variable equals zero when there are no missing single women; its mean is .25, and it ranges from .06 to .39, and it can be constructed for 22 counties. Next, we examine the link between the measure with broader coverage – $\%TaxDrop$ – and $\ln\left(M_{\text{single}}/W_{\text{single}}\right)$. Figure B.8 shows that these measures are strongly positively correlated.

Figure B.8: Excess Single Men and Drop in 1381 Poll Tax Payers



Notes: The y-axis plots the residual variation (after controlling for population density in 1290) in the county-level drop in tax payers between the 1377 and 1381 poll tax. County-level poll tax data for 1377 and 1381 are from Fenwick (1998, 2001, 2005). To obtain gender and marital status, we sample 193 settlements, as described in detail in Section B.6 and Table B.9.

In Table B.6, Columns 1-3 show that missing single women are strongly associated with the drop in tax revenues. Our proxy itself accounts for 27% of the variation in tax payer reduction (column 1), and together with county population density it can explain 47% of the variation (column 2). The coefficient on population density is negative – as expected if it is easier to evade tax collection in more remote areas. Column 3 shows

[20]Unfortunately, directly counting the number of unmarried women in 1377 – when tax evasion was low – is not an option. Only a handful of counties have surviving information at the settlement level that could be used.

that this finding is robust to controlling for regional fixed effects. The remainder of Table B.6 shows that the results are driven by a low proportion of unmarried women (columns 4-6), but not by unmarried men (columns 7-9).

Table B.6: 'Missing' unmarried women and the drop in poll tax payers, 1377-81

Dependent Variable: Drop in Tax Payers at the County Level, 1377-1381

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\ln(M_{\text{single}}/W_{\text{single}})$	.111**	.119***	.132***						
	(.044)	(.037)	(.026)						
$W_{\text{single}}/N_{\text{sample}}$				-1.389**	-1.308***	-2.053***			
				(.523)	0.413	0.315			
$M_{\text{single}}/N_{\text{sample}}$							.141	.714	.499
							(.430)	(.527)	(.673)
$\ln(popdensity^{1290})$		-.110**	-.286***		-.0885	-.346***		-.126*	-.245*
		(.049)	(.081)		(.059)	(.058)		(.071)	(.121)
Region FE	no	no	yes	no	no	yes	no	no	yes
R^2	.273	.473	.683	.262	.392	.746	.003	.222	.368
Observations	22	22	22	22	22	22	22	22	22

Notes: Robust standard errors in parentheses. Key: *** significant at 1%; ** 5%; * 10%. The dataset consists of 22 counties for which detailed records from the 1381 English poll tax has survived. M_{single} and W_{single} reflect the number of unmarried men and women, respectively. These are derived based on sampling 193 hundreds (sub-parish level), where N_{sample} denotes the total number of sampled tax payers at the county level (ranging 316–1,963 with a mean of 776); this variable is used as analytical regression weight. $popdensity$ is the population per square mile at the county level in 1290 from Broadberry et al. (2011).

How important was pastoralism for late marriage or celibacy in the 14th century? To gauge magnitudes, we need the proportion of unmarried women. However, we cannot construct this direct measure because single women are underreported in the poll tax data. Instead, we use the proportion of unmarried *men* as a proxy. As before, this variable can be constructed for the 22 counties with detailed tax records. Figure B.9 shows that it correlates strongly with the share of pastoral land in 1290. After controlling for population density, the coefficient is .244 with a standard error of .086.[21] Thus, a one-standard deviation increase in $Pastoral^{1290}$ (.15) is associated with an increase of 3.7% in the share of unmarried men.[22]

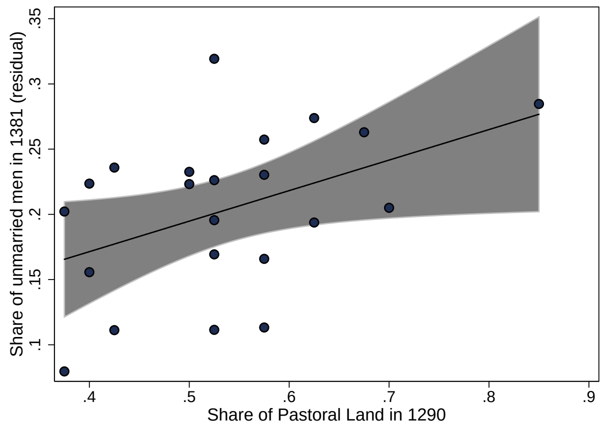
Drop in Tax Payers at the County Level

While tax rolls listing individual names and marital status survived for only 22 counties, the overall number of tax payers in 1377 and 1381 is available for 38 English counties. We use these data in the paper. Figure B.10 shows that tax evasion in 1381 was a broad phenomenon across all regions in England.

[21] The coefficient is almost identical but marginally insignificant when we additionally include regional fixed effects.

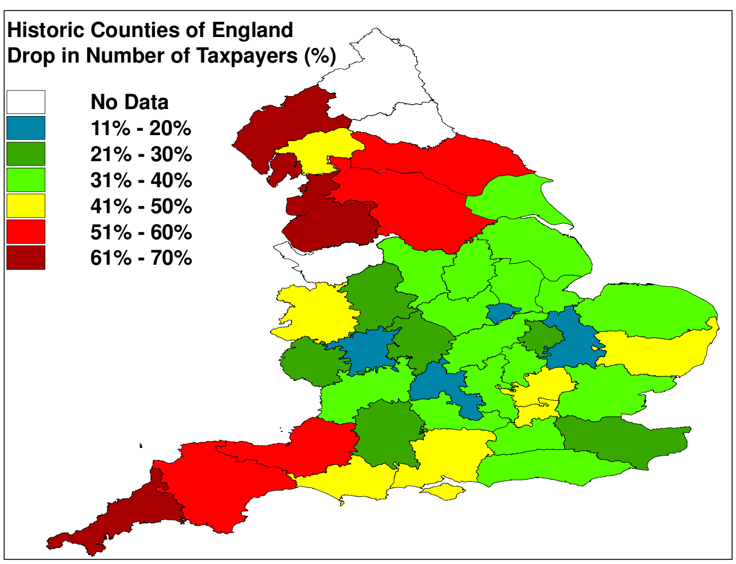
[22] This figure has to be interpreted with caution. The share of unmarried men in the observed population is mechanically higher where many unmarried women evaded the poll tax, because then the denominator is lower.

Figure B.9: Unmarried men in the 1381 Poll Tax (partial scatterplot)



Notes: The y-axis plots the residual variation in unmarried men relative to total population, after controlling for county-level population density in 1290. To obtain gender and marital status, we sample 193 settlements from Fenwick (1998, 2001, 2005), as described in detail in Appendix B.6 and Table B.9. See note to Figure B.4 for share of pastoral land in 1290.

Figure B.10: Spatial distribution of drop in poll tax payers 1377-81



Notes: The figure shows the percentage drop of the number of tax payers in each county between 1377 and 1381. The data is from Fenwick (1998, 2001, 2005).

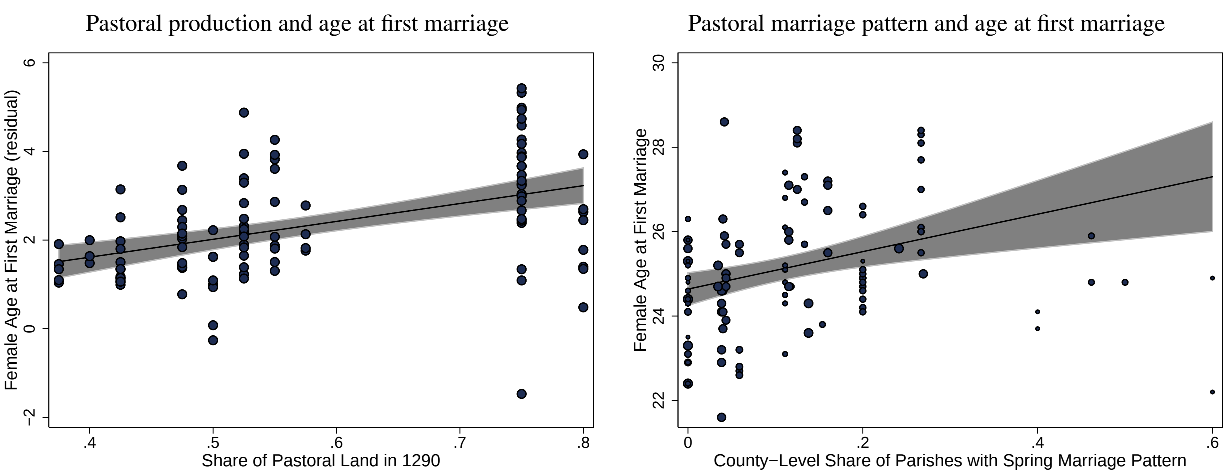
B.7 Female Marriage Age and Patterns of Land Use

In this appendix, we provide additional information on the relationship between deserted medieval villages, pastoral marriage patterns, and the female age at first marriage.

Age at Marriage, Pastoral Production, and Farm Service

We begin by showing that our results in Tables 4 and 5 in the paper are not driven by outliers. The left panel of Figure B.11 shows the (partial) scatterplot for the first regression in Table 4. There, we estimate a panel structure based on 26 parishes in 15 counties over 5 periods. Our estimates control for period fixed effects, and standard errors are clustered at the county level. Thus, we exploit the cross-county variation. To provide a complete overview of the underlying data, we plot all data points used in the regression. The right panel of Figure B.11 shows the scatterplot corresponding to the first regression in Table 5. This specification exploits both time-series and cross-sectional variation in the spring marriage pattern and the female age at first marriage. It uses the number of parishes in each county for which the pastoral marriage pattern is reported in Kussmaul (1990) as analytical weights. The size of the dots in the figure is proportional to these weights.

Figure B.11: Scatterplots Corresponding to Tables 4 and 5 in the Paper



Notes: The left panel shows the partial scatterplot corresponding to the first regression in Table 4. The y-axis plots the residual variation in the age at first marriage, after controlling for DMV (Deserted Medieval Villages) and period fixed effects. The right panel shows the scatterplot for the first regression in Table 5 (panel A). All regressions in this table are weighted by the number of parishes in each county for which the pastoral marriage pattern is reported in Kussmaul (1990). The size of the dots in the figure is proportional to these weights. See the notes to Tables 4 and 5 in the paper for further descriptions.

Deserted Medieval Villages and Age at Marriage

We use data on abandoned medieval villages to capture agricultural change after the Black Death (Beresford, 1989). This information has been widely used as an indicator of agricultural change after the Black Death. For example, Broadberry et al. (2011) conclude that:

> One guide to the scale and geographical extent of this shift is provided by a simple count of the numbers of deserted medieval villages (DMVs) in each county...in a band of counties stretching north-east to south-west through the heart of the midlands, potentially at least 1/2 million acres of land which had been in arable production before the Black Death may have been converted to permanent grassland thereafter and much of it, even at the height of the ploughing-up campaign of the Napoleonic Wars, was never converted back.

From the CAMPOP dataset, we take the average age of first marriage for women in each parish. The number of deserted villages per 100,000 acres in each county is our indicator for the extent to which the switch from "corn to horn" occurred after 1350. In Figure B.12, we plot the kernel density of marriage ages, conditional on the share of deserted villages being above or below the median. The distribution is clearly shifted to the right, with a difference in modes of one year.

Figure B.12: Deserted medieval villages and female age at marriage (kernel density)

Notes: Mean age at first marriage is from CAMPOP Wrigley, Davies, Oeppen, and Schofield (1997); we use the parish-level average over all five CAMPOP periods between 1600 and 1837. Deserted medieval villages per 100,000 acres (DMV) are from Broadberry et al. (2011). DMV serve as a proxy for the shift from arable to pastoral production after the Black Death.

Pastoral Production and Age at Marriage

In Table B.7 we show that a higher share of pastoral land use in 1836 (when the measure is available directly from the tithe records) has a similar effect as our variable for 1290. This underlines the long-run stability of effects shown in Table 4 in the paper.[23]

Pastoral Marriage Pattern

As mentioned in the text, Kussmaul (1990) provides data on the pastoral (spring) marriage pattern for 542 parishes over 3 periods: 1561-1640, 1641-1740, and 1741-1820. We match these as follows to the five

[23] $Pastoral^{1836}$ is available for 28 counties only. In specifications with $Pastoral^{1836}$ we do not include DMV, because the variable should already reflect the post-plague shift "from corn to horn."

Table B.7: Pastoral Production and Age at First Marriage (Parish-Level Panel)

Dependent Variable: Female Age at First Marriage

	(1) OLS	(2) OLS	(3) IV	(4) OLS	(5) OLS	(6) IV
Period	1600-1837			1600-1749		
$Pastoral^{1836}$	3.622***	7.580**	4.502***	4.177***	7.842	4.812***
	(.804)	(3.293)	(.706)	(.867)	(5.101)	(.703)
Period FE	yes	yes	yes	yes	yes	yes
Region FE	no	yes	no	no	yes	no
R^2	.577	.715	-	.417	.591	-
Observations	83	83	83	49	49	49
Instrument			$\ln(daysgrass)$			$\ln(daysgrass)$
First Stage F-Statistic$^{\#}$			47.0			51.7

Notes: The panel comprises 26 parishes (located in 15 counties) over 5 periods. All explanatory variables and the instrument are measured at the county level, while the dependent variable is observed at the parish level. Robust standard errors in parentheses (clustered at the county level). Key: *** significant at 1%; ** 5%; * 10%. $Pastoral^{1836}$ is the fraction of grass and commons in the total county area in 1836, and $daysgrass$ denotes the days per year during which grass grows at the county level (see Appendix B.5 for detail).

$^{\#}$ Kleibergen-Paap rK Wald F statistic (cluster-robust). The corresponding Stock-Yogo value for 10% maximal IV bias is 16.4 in both columns 3 and 6.

periods in CAMPOP (Wrigley et al., 1997): 1561-1640 –> 1600-40; 1641-1740 –> 1650-99 and 1700-49; 1741-1820 –> 1750-99 and 1800-37.

Figure B.13 shows the relationship between the share of pastoral land in 1290 and our proxy for pastoral service ($PastoralMarriage$) for a cross-section of 40 counties. The corresponding regression (weighted by the number of Kussmaul parishes in each county) has a coefficient of 0.389 (0.139) and is significant at the 1% level.

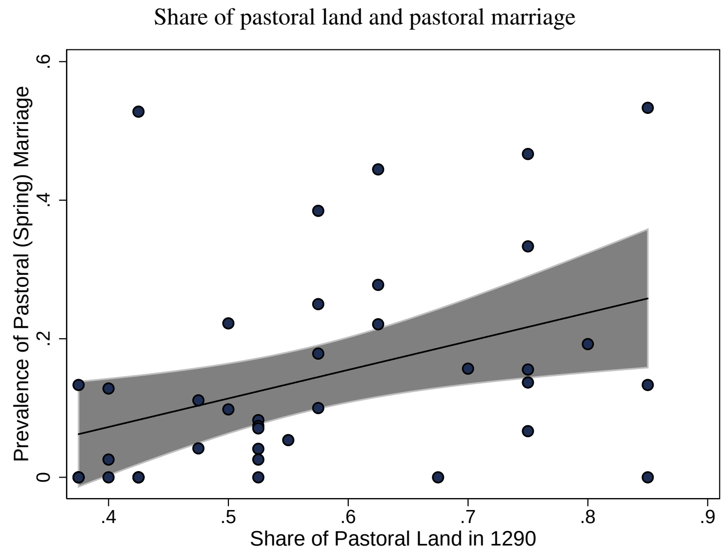
B.8 Evidence from the 1851 Census

Although our main focus of analysis is the period before 1800, we can exploit the detailed data available in mid-19th century censuses to illustrate the main mechanism that linked farm service for women and delayed marriage. Farming was a declining part of the English economy. Nonetheless, areas that employed servants in agricultural production still saw markedly later marriage ages. In the following, we describe the data in detail and then present our empirical results.

Variables from the 1851 Census

We collect county-level information on civil condition and occupations from the 1851 British Census, Volume I (Eyre and Spottiswoode, 1854). Civil conditions comprise bachelors, spinsters, husbands, wives, widowers, and widows, all aged 20 or older. We calculate the share of unmarried women as spinsters, divided by the sum of wives, spinsters, and widows. Thus, our measure reflects women who have never been

Figure B.13: Pastoral Land, and Spring Marriage



Source: County-level arable acreage in 1290 is from Broadberry et al. (2011). To obtain the prevalence of pastoral marriage, we take the county-level average across all parishes reported by Kussmaul (1990) that are located in the respective county.

married – the relevant group for our argument. The census also lists detailed occupations in agriculture (for both male and female workers), including farmers, graziers, agricultural labourers, shepherds, cowkeepers/milksellers, and farm servants. We define the variable $\%AgServants$ as the number of farm servants, divided by all listed occupational categories in agriculture. In addition, we define the more specific category $\%AgServants_{\text{female}}$, which includes only female servants in the numerator. Finally, we extract the number of employees in 'chief manufactures and products,' and divide it by the total population aged 20 and above to obtain the variable $\%ManufEmp$.

Empirical Results

In Table B.8, we investigate the link between pastoral employment in agriculture and marriage probabilities. The dependent variable is the ratio of spinsters (unmarried, but not widowed) to all women aged 20 or older, in each county. Where many females remained unmarried until late in life, average age at first marriage must have been high. The ratio of single women has a mean of .28 and a standard deviation of .027 across 41 counties. We use two explanatory variables. First, the share of female agricultural servants in total agricultural employment ($\%AgServants_{\text{female}}$) captures the demand for *women* as servants in agriculture. Second, we use the share of *all* agricultural servants in total agricultural employment ($\%AgServants$). This reflects the strength of hiring labor year-long in agriculture in general; it is also the explanatory variable used by Kussmaul (1981). Columns 1 and 2 show a positive correlation between $\%AgServants_{\text{female}}$ and the proportion of single women. The statistical significance of this result increases when we use $\%AgServants$ instead (columns 4 and 5). The number of agricultural servants reported in the census does not differentiate between arable and pastoral farms. One way to address this issue is by instrumenting with pastoral land suitability (days of grass-growing). Because our story relies on animal husbandry, we expect the coefficients to increase when we isolate this channel by IV estimation. Columns 4 and 6 show that, for both explanatory variables, results are stronger when we instrument. According to these estimates, farm service was powerfully associated with a higher proportion of unmarried females. A one standard deviation increase in $\%AgServants_{\text{female}}$ pushes up the the proportion of single women by up to 3.5 percentage points. The same proportional increase of $\%AgServants$ raises the dependent variable by 3.9 percentage points. In levels (using the means of the explanatory variables), pastoral farm service raises the proportion of single women by 5.6–6.8 percentage points. Interestingly, we also find a negative effect of the share of manufacturing employment. This suggests that as industrial employment opportunities increased, the European Marriage Pattern declined.

Table B.8: Celibacy and Service Employment in Agriculture in the 1851 British Census

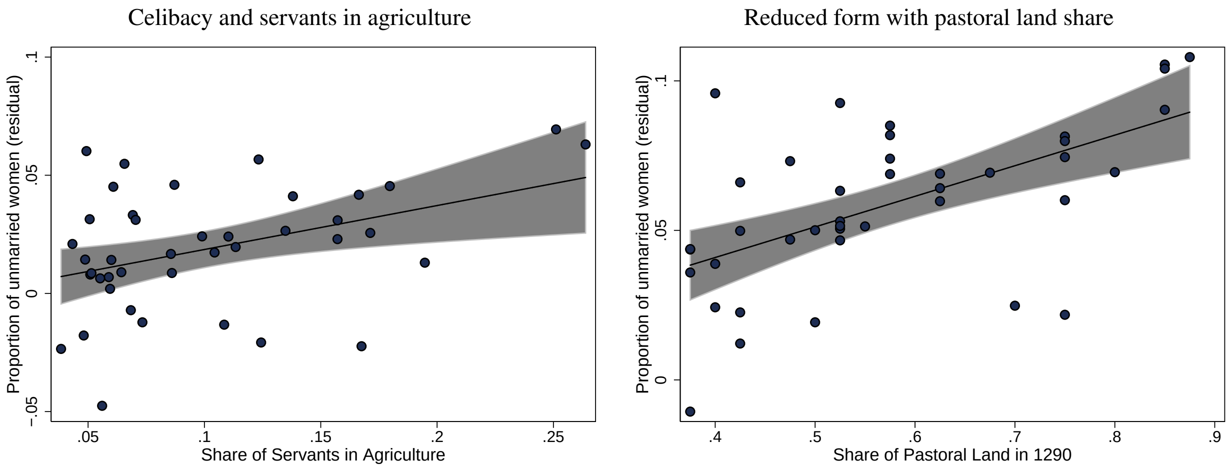
Dependent Variable: Proportion of Unmarried Women in Female Population over 20

	(1) OLS	(2) OLS	(3) IV	(4) OLS	(5) OLS	(6) IV
$\%AgServants_{\text{female}}$	.335	.387*	1.766**			
	(.229)	(.210)	(.773)			
$\%AgServants$				.141*	.186***	.681***
				(.073)	(.062)	(.214)
$\%Manuf$		-.0626*	-.0969**		-.0781**	-.145***
		(.034)	(.049)		(.032)	(.053)
R^2	.06	.14	-	.09	.20	-
Observations	41	41	41	41	41	41
Instrument			$\ln(daysgrass)$			$\ln(daysgrass)$
First Stage F-Statistic#			15.8			13.4

Notes: Robust standard errors in parentheses. Key: *** significant at 1%; ** 5%; * 10%. The dependent variable is defined as the share of spinsters (unmarried, but not widowed) in the population over 20 years old. $\%AgServants_{\text{female}}$ and $\%AgServants$ are, respectively, the shares of female and all agricultural servants in total agricultural employment. $\%Manuf$ is the employment share in manufacturing.
Kleibergen-Paap rK Wald F statistic (cluster-robust). The corresponding Stock-Yogo value for 10% maximal IV bias is 16.4 in both columns 5 and 6.

Figure B.14 complements the evidence provided above. The left panel shows the relationship between agricultural service and the proportion of single women, after controlling for manufacturing employment (this corresponds to column 5 in Table B.8). The right panel performs an additional analysis, regressing the fraction of single women directly on the historical share of pastoral land (again, after controlling for $\%ManufEmp$. The coefficient on $Pastoral^{1290}$ is .102 (.023). Given that the average of $Pastoral^{1290}$ is .57, this estimate implies that pastoral production raises the share of unmarried women by about 5.7 percentage points countrywide.

Figure B.14: Pastoral Land, Servants in Agriculture, and Celibacy in 1851 (partial scatterplots)



Notes: The y-axis plots the residual variation in the share of unmarried women (in population aged above 20), after controlling for the employment share in manufacturing. Employment shares and civil conditions are from the 1851 British Census (Eyre and Spottiswoode, 1854). See note to Figure B.4 for share of pastoral land in 1290.

B.9 Additional Historical Evidence

On the use of poll tax data as an indicator of the share of unmarried women (Oman, 1906):

> The result was that *every shire of England returned an incredibly small number of adult inhabitants liable to the impost*. This can be proved with absolute certainty by comparing the returns of the earlier...Poll-tax of 1377 with those of this...Poll-tax of 1381. ...*The adult population of the realm had ostensibly fallen from 1,355,201 to 896,481 persons. These figures were monstrous and incredible* – in five years, during which the realm, though far from being in a flourishing condition, had yet been visited neither by pestilence, famine, nor foreign invasion, the ministers were invited to believe that its population had fallen off in some districts more than 50 per cent, in none less than 20 per cent...
>
> A glance at the details of the township-returns...reveals the simple form of evasion which the villagers had practised when sending in their schedules. They had suppressed the existence of their unmarried female dependants, ... The result is that most villages show an enormous and impossible predominance of males in their population, and an equally *incredible want of unmarried females*. When therefore we find Essex or Suffolk or Staffordshire townships returning, one after another, a population working out in the proportion of five or four males to four or three females, we know what to conclude. [our emphasis]

Table B.9: List of Sampled Settlements from the 1381 Poll Tax

	County	# Settlem. per county	Name of Settlement	Type of Settlement	# of People in Sample
1	Berkshire	10	Shaw	rural	16
2	Berkshire	10	Faringdon	rural	195
3	Berkshire	10	Bercote	rural	35
4	Berkshire	10	Enborne	rural	73
5	Berkshire	10	East Hanney	rural	41
6	Berkshire	10	Burghfield	rural	25
7	Berkshire	10	Idstone	rural	46
8	Berkshire	10	Balking	rural	18
9	Berkshire	10	Steventon	rural	171
10	Berkshire	10	Grove	rural	117
11	Derbyshire	10	Youlgrave	rural	231
12	Derbyshire	10	Darley	rural	246
13	Derbyshire	10	Tideswell	rural	165
14	Derbyshire	10	Wormhill	rural	331
15	Derbyshire	10	Bakewell	rural	166
16	Derbyshire	10	Buxton	rural	126
17	Derbyshire	10	Baslow	rural	292
18	Derbyshire	10	Glossop	rural	118
19	Derbyshire	10	Blackwell	rural	26
20	Derbyshire	10	Castleton	rural	262
21	Dorset	10	Wareham	rural	150
22	Dorset	10	Radipole	rural	33
23	Dorset	10	Tyneham	rural	5
24	Dorset	10	Hanford	rural	19
25	Dorset	10	Afflington	rural	22
26	Dorset	10	[name unknown]	rural	4
27	Dorset	10	Bishop's Candle	rural	15
28	Dorset	10	Kyngeston	rural	22
29	Dorset	10	Chartlon and Herrington	rural	17
30	Dorset	10	W[...]	rural	29
31	Essex	10	West Ham	rural	239
32	Essex	10	Broomfield	rural	34
33	Essex	10	Leaden Roding	rural	39
34	Essex	10	Foxearth	rural	63
35	Essex	10	Lamarsh	rural	43
36	Essex	10	Bobbingworth	rural	48
37	Essex	10	Chigwell	rural	123
38	Essex	10	LittkeBentley	rural	46
39	Essex	10	GreatTotham	rural	71
40	Essex	10	Witham	rural	58
41	Gloucestershire	10	Frampton Mansell	rural	19
42	Gloucestershire	10	Hampnett	rural	19
43	Gloucestershire	10	Hatherop	rural	50
44	Gloucestershire	10	Bagendon	rural	7
45	Gloucestershire	10	Postlip	rural	23
46	Gloucestershire	10	Admington	rural	72

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Table B.9 – continued from previous page

	County	# Settlem. per county	Name of Settlement	Type of Settlement	# of People in Sample
47	Gloucestershire	10	Rodborough	rural	62
48	Gloucestershire	10	North Cerney	rural	26
49	Gloucestershire	10	Lower Swell	rural	44
50	Gloucestershire	10	Ashton Under Hill	rural	65
51	Hampshire	10	Amport	rural	18
52	Hampshire	10	Quarley	rural	106
53	Hampshire	10	[...]ute	rural	61
54	Hampshire	10	Pokesole	rural	31
55	Hampshire	10	North Fareham	rural	12
56	Hampshire	10	Hambledon	rural	49
57	Hampshire	10	Chilworth	rural	18
58	Hampshire	10	Portsea	rural	32
59	Hampshire	10	[name unknown]	rural	86
60	Hampshire	10	[name unknown]	rural	8
61	Kent	1	Canterbury	urban	445
62	Lancashire	10	Salford	rural	35
63	Lancashire	10	Bolton	rural	35
64	Lancashire	10	Heaton Norris	rural	29
65	Lancashire	10	Castleton	rural	20
66	Lancashire	10	Chortlong Upon Medlock	rural	12
67	Lancashire	10	Hale	rural	73
68	Lancashire	10	Aughton	rural	65
69	Lancashire	10	Sutton	rural	43
70	Lancashire	10	Abram	rural	17
71	Lancashire	10	Much Woolton	rural	20
72	Leicestershire	10	Wyfordby	rural	37
73	Leicestershire	10	Bottesford	rural	156
74	Leicestershire	10	Croxton Kerrial	rural	67
75	Leicestershire	10	Stockerston	rural	37
76	Leicestershire	10	Great Glen	rural	110
77	Leicestershire	10	Queninborough	rural	107
78	Leicestershire	10	Barrow Upon Soar	rural	67
79	Leicestershire	10	Loddington with Launde	rural	117
80	Leicestershire	10	Braunstone	rural	79
81	Leicestershire	10	Shenton	rural	110
82	Lincolnshire	10	Whaplode	rural	725
83	Lincolnshire	10	Holbeach	rural	399
84	Lincolnshire	10	Benington	rural	126
85	Lincolnshire	10	Butterwick	rural	118
86	Lincolnshire	10	Fishtoft	rural	193
87	Lincolnshire	10	Skirbeck	rural	140
88	Lincolnshire	10	Swarby	rural	27
89	Lincolnshire	10	Totill and South Reston	rural	59
90	Lincolnshire	10	Mablethorpe	rural	57
91	Lincolnshire	10	Belleau and Aby	rural	60
92	Norfolk	10	Wereham	rural	51
93	Norfolk	10	StowBardolph with Wimbotsham	rural	113

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Table B.9 – continued from previous page

	County	# Settlem. per county	Name of Settlement	Type of Settlement	# of People in Sample
94	Norfolk	10	Denver	rural	66
95	Norfolk	10	Beetley	rural	74
96	Norfolk	10	Colkirk	rural	50
97	Norfolk	10	East Brandenham	rural	32
98	Norfolk	10	HolmeHale	rural	35
99	Norfolk	10	Ridlington	rural	71
100	Norfolk	10	NorthWalsham	rural	153
101	Norfolk	10	Crostwight	rural	44
102	Northamptonshire	7	Wellingborough	rural	142
103	Northamptonshire	7	EastonMaudit	rural	49
104	Northamptonshire	7	KingsCliffe	rural	147
105	Northamptonshire	7	Southwick	rural	32
106	Northamptonshire	7	Fotheringhay	rural	74
107	Northamptonshire	7	Duddington	rural	66
108	Northamptonshire	7	[name unknown]	rural	55
109	Oxfordshire	12	Banbury	rural	52
110	Oxfordshire	12	Neithrop and Calthorpe	rural	44
111	Oxfordshire	12	Adderbury	rural	85
112	Oxfordshire	12	Arncott	rural	33
113	Oxfordshire	12	Radford	rural	30
114	Oxfordshire	12	Fifield	rural	40
115	Oxfordshire	12	Mongewell Cadwell and Huntercombe	rural	27
116	Oxfordshire	12	Warborough and Ganglesdown	rural	124
117	Oxfordshire	12	StMary Magdalen	urban	156
118	Oxfordshire	12	StGiles	urban	60
119	Oxfordshire	12	Attington	rural	26
120	Oxfordshire	12	Waterstock	rural	50
121	Shropshire	10	Fauls Willaston and Adderley	rural	51
122	Shropshire	10	Halesowen	rural	95
123	Shropshire	10	Waltone	rural	23
124	Shropshire	10	Marrington and Walcot	rural	62
125	Shropshire	10	CondoverwithParcels	rural	50
126	Shropshire	10	Rowton with Parcels	rural	40
127	Shropshire	10	Minsterley	rural	44
128	Shropshire	10	Coleham	rural	33
129	Shropshire	10	Alveley	rural	78
130	Shropshire	10	Wrickton and Walkerslow	rural	28
131	Somerset	9	Bath	urban	295
132	Somerset	9	Hardington Mandeville	rural	22
133	Somerset	9	Sutton Bingham	rural	13
134	Somerset	9	Closworth	rural	44
135	Somerset	9	WestCoker	rural	56
136	Somerset	9	Hardington Marsh	rural	10
137	Somerset	9	Chilton Cantelo	rural	21
138	Somerset	9	Pendomer	rural	8
139	Somerset	9	EastCoker	rural	8
140	Staffordshire	11	Moreton and Wilbrighton	rural	47

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Table B.9 – continued from previous page

	County	# Settlem. per county	Name of Settlement	Type of Settlement	# of People in Sample
141	Staffordshire	11	High Onn	rural	33
142	Staffordshire	11	Rugeley	rural	156
143	Staffordshire	11	Gnosall	rural	61
144	Staffordshire	11	Essington Coven and Stretton	rural	73
145	Staffordshire	11	Lichfield	urban	667
146	Staffordshire	11	Curborough and Elmhurst	rural	50
147	Staffordshire	11	Norton Canes and Little Wirley	rural	37
148	Staffordshire	11	Pipe Ridware and Packington	rural	48
149	Staffordshire	11	Mavesyn Ridware	rural	99
150	Staffordshire	11	West Bromwich	rural	60
151	Suffolk	10	Langham	rural	89
152	Suffolk	10	Buxlow	rural	28
153	Suffolk	10	Bulcamp	rural	31
154	Suffolk	10	Hadleigh	rural	312
155	Suffolk	10	Thwaite	rural	46
156	Suffolk	10	Mildenhall	rural	396
157	Suffolk	10	Flixton	rural	116
158	Suffolk	10	[name unknown]	rural	127
159	Suffolk	10	Gipping	rural	43
160	Suffolk	10	Chevington	rural	63
161	Surrey	10	Wotton	rural	67
162	Surrey	10	Dorking	rural	279
163	Surrey	10	Abinger	rural	20
164	Surrey	10	Shere	rural	166
165	Surrey	10	Westcott	rural	59
166	Surrey	10	Godalming	rural	238
167	Surrey	10	Farncombe	rural	56
168	Surrey	10	Chiddingfold	rural	176
169	Surrey	10	Hurtmore	rural	13
170	Surrey	10	Hambledon	rural	23
171	Sussex	1	Chichester	urban	474
172	Wiltshire	11	Throope	rural	33
173	Wiltshire	11	Croucheston	rural	72
174	Wiltshire	11	Bishopstone	rural	46
175	Wiltshire	11	Wick	rural	26
176	Wiltshire	11	Stourton	rural	53
177	Wiltshire	11	Mere	rural	144
178	Wiltshire	11	Charnage	rural	33
179	Wiltshire	11	WestKnoyle	rural	50
180	Wiltshire	11	Zeals	rural	131
181	Wiltshire	11	Salisbury	urban	304
182	Wiltshire	11	Netton	rural	40
183	Worcestershire	1	Worcester	urban	410
184	YorkshireER	10	Thornthorpe	rural	14
185	YorkshireER	10	Fimber	rural	45
186	YorkshireER	10	Westow	rural	54

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Table B.9 – continued from previous page

	County	# Settlem. per county	Name of Settlement	Type of Settlement	# of People in Sample
187	YorkshireER	10	Acklam with Leavening	rural	34
188	YorkshireER	10	Holme on the Woods	rural	64
189	YorkshireER	10	Hayton	rural	69
190	YorkshireER	10	Lomdesborough	rural	32
191	YorkshireER	10	Naburn	rural	47
192	YorkshireER	10	Fulford	rural	47
193	YorkshireER	10	Cottyngwyth	rural	44

Notes: The sampling procedure is described in Section B.6. Underlying settlement data for the 1381 poll tax are from Fenwick (1998, 2001, 2005).

References

Alesina, A., P. Giuliano, and N. Nunn (2011). On the Origins of Gender Roles: Women and the Plough. NBER WP 17098.

Allen, R. C. (1988). The Growth of Labor Productivity in Early Modern English Agriculture. *Explorations in Economic History 25*, 117–146.

Allen, R. C. (1991). The Two English Agricultural Revolutions, 1450-1850. In B. Campbell and M. Overton (Eds.), *Land, Labour, and Livestock: Historical Studies in European Agricultural Productivity*, pp. 236–254. Manchester: MUP.

Allen, R. C. (1992). *Enclosure and the Yeoman*. Oxford: Oxford University Press.

Allen, R. C. (2009). Agricultural Productivity and Rural Incomes in England and the Yangtze Delta, c. 1620–c.1820. *Economic History Review 62*(3), 525–550.

Anderson, M. and R. Lee (2002). Malthus in State Space: Macro Economic-demographic Relations in English History, 1540 to 1870. *Journal of Population Economics 15*, 195–220.

Beresford, M. (1989). A Review of Historical Research (to 1968). In M. Beresford and J. G. Hurst (Eds.), *Deserted Medieval Villages*, pp. 3–75. Gloucester: Alan Sutton.

Berkeley, C. G. (1963). *Agricultural Involution: The Process of Ecological Change in Indonesia*. Berkeley, CA: University of California Press.

Brenner, R. and C. Isett (2002). England's Divergence from China's Yangtze Delta: Property Rights, Microeconomics, and Patterns of Development. *Journal of Asian Studies 61*(2), 609–662.

Broadberry, S., B. M. S. Campbell, and B. van Leeuwen (2011). Arable Acreage in England, 1270-1871. Working Paper.

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

Down, K., J. Jollans, A. Lazenby, and R. Wilkins (1981). The Distribution of Grassland and Grassland Usage in the UK. In J. Jollans (Ed.), *Grassland in the British Economy*, Number 10, pp. 580–583. Reading: University of Reading: Centre for Agricultural Strategy.

Eyre, G. E. and W. Spottiswoode (1854). Population Tables II. Ages, Civil Condition, Occupations, and Birth-Place of the People. Vol. I. In *Census of Great Britain, 1851*. House of Commons Parliamentary Papers.

FAO/IIASA (2010). Global Agro-ecological Zones (GAEZ) version 3.0. Technical report, IIASA, Laxenburg, Austria and FAO, Rome, Italy.

Feng, W., J. Lee, and C. Campbell (1995). Marital Fertility Control Among the Qing Nobility: Implications for Two Types of Preventive Check. *Population Studies 49*(3), 383–400.

Fenwick, C. (Ed.) (1998). *The Poll Taxes of 1377, 1379, and 1381: Bedfordshire-Leicestershire*. Oxford University Press for British Academy Records of Social and Economic History.

Fenwick, C. (Ed.) (2001). *The Poll Taxes of 1377, 1379 and 1381: Lincolnshire-Westmorland*. Oxford University Press for British Academy Records of Social and Economic History.

Fenwick, C. (Ed.) (2005). *The Poll Taxes of 1377, 1379 and 1381: Wiltshire - Yorkshire*. Oxford University Press for British Academy Records of Social and Economic History.

Goldstone, J. (2003). Feeding the People, Starving the State: China's Agricultural Revolution of the 17th and 18th Centuries. *Global Economic History Network Conference. London*.

Kain, R. J. (1986). *An Atlas and Index of the Tithe Files of Mid-Nineteenth-Century England and Wales*. Cambridge University Press.

Kelly, M. and C. Ó Grada (2010). Living Standards and Mortality since the Middle Ages. Working Papers 2010/26, School Of Economics, University College Dublin.

Kussmaul, A. (1981). *Servants in Husbandry in Early Modern England*. Cambridge, CUP.

Kussmaul, A. (1990). *A General View of the Rural Economy of England, 1538-1840*. Cambridge: Cambridge University Press.

Lee, J. and W. Feng (1999). Malthusian Models and Chinese Realities: The Chinese Demographic System 1700–2000. *Population and Development Review 25*(1), 33–65.

Li, B. (1998). *Agricultural Development in Jiangnan, 1620-1850*. New York: St. Martin's Press.

Maddison, A. (2001). *The World Economy. A Millennial Perspective*. Paris: OECD.

Mingay, G. E. and J. Thirsk (Eds.) (2011). *The Agrarian History of England and Wales, 1750-1850*, Volume VI. Cambridge University Press.

Minge-Klevana, W. (1980). Does Labor Time Decrease With Industrialization? A Survey of Time-Allocation Studies. *Current Anthropology 21*(3), 279–298.

Murdock, G. P. and C. Provost (1973). Factors in the Division of Labor by Sex: A Cross-Cultural Analysis. *Ethnology 12*(2), 203–225.

Oman, C. (1906). *The Great Revolt of 1381*. Oxford : Clarendon Press.

Smith, R. M. (2011). Demography and the Great Divergence: Reconsidering the European and Asian Evidence. Keynote address at the Economic History Society Conference, Cambridge, UK 2011.

Voigtländer, N. and H.-J. Voth (2013). The Three Horsemen of Riches: Plague, War, and Urbanization in Early Modern Europe. *Review of Economic Studies*. Forthcoming.

Wrigley, E. A., R. S. Davies, J. E. Oeppen, and R. S. Schofield (1997). *English Population History from Family Reconstitution 1580-1837*. New York: Cambridge University Press.